

# State of Arizona Hazard Mitigation Plan

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2018





The 2018 State of Arizona Hazard Mitigation Plan is a result of collaboration between state agencies and partners, led by the Arizona Department of Emergency and Military Affairs. For more information on this plan, contact:

DEMA Planning Branch

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The 2018 State of Arizona Hazard Mitigation Plan is located at:

<https://dema.az.gov/emergency-management/preparedness/planning-branch>

## EXECUTIVE SUMMARY

Natural and human-caused disasters have led to increasing levels of death, injury, property damage, and interruption of business and government services. The time, money, and effort to respond to and recover from these disasters divert public resources and attention from other important programs and problems. Arizona recognizes the consequences of disasters and the critical need to reduce the impacts of natural and human-caused hazards.

It is understood that with careful selection, mitigation measures in the form of education, structural projects, and programs can become long-term, cost effective means for reducing the impact of natural and human-caused hazards. The State of Arizona Hazard Mitigation Planning Team (the Planning Team) has collaborated to prepare the *2018 State of Arizona Hazard Mitigation Plan* (the Plan). With the support of the State of Arizona and the Federal Emergency Management Agency (FEMA), this Plan has resulted in a resource to guide the state toward greater disaster resistance in full harmony with the needs of the region.

Arizona's hazards have the potential to cause widespread loss of life and damage to property, infrastructure, the economy, and the environment. Hazard mitigation is designed to reduce or eliminate risk, by reducing the probability and severity of hazardous events. Mitigation is any sustained action taken to reduce or eliminate long-term risk to life and property, and successful implementation can reduce the enormous cost burden disasters place on individuals in the community and all levels of government. Mitigation can protect critical community facilities, reduce liability, and minimize community disruption. Preparedness, response, and recovery measures support the concept of mitigation and may directly support identified mitigation measures.

This Plan has been prepared in compliance with Section 322 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act or the Act), 42 USC. 5165, enacted under Sec. 104 the Disaster Mitigation Act of 2000, (DMA 2000) Public Law 106-390 of October 30, 2000. This Plan identifies hazard mitigation measures intended to eliminate or reduce the effects of future disasters throughout the state.



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**FEMA**

October 25, 2018

Wendy Smith-Reeve  
Director  
Arizona Department of Emergency and Military Affairs  
5636 East McDowell Road  
Phoenix, AZ 85008

Dear Ms. Smith-Reeve:

The Federal Emergency Management Agency (FEMA) Region IX, Mitigation Division has approved the *2018 State of Arizona Hazard Mitigation Plan* (the Plan) effective October 25, 2018 through October 24, 2023, in accordance with the planning requirements of Title 44 Code of Federal Regulations (CFR) § 201.4, *Standard State Hazard Mitigation Plans*.

A FEMA-approved state mitigation plan is a condition of receiving certain non-emergency Stafford Act assistance and FEMA mitigation grants from the following sources:

- Public Assistance Categories C-G (PA C-G)
- Fire Management Assistance Grants (FMAG)
- Hazard Mitigation Grant Program (HMGP)
- Pre-Disaster Mitigation (PDM)
- Flood Mitigation Assistance (FMA)

The Plan also meets the requirements set forth in 44 CFR § 201.4(c)(3)(v) and qualifies the State of Arizona to request an increased Federal share for repetitive loss properties under the Flood Mitigation Assistance (FMA) program.

State hazard mitigation plans must be updated and resubmitted to the FEMA for approval every five years. If the Plan is not updated and approved by October 24, 2023, the Plan is considered lapsed and FEMA will not obligate funds. If the State of Arizona is not complying with all applicable Federal statutes and regulations in effect at any time over the plan approval period, FEMA may take action to correct the noncompliance (44 CFR §§ 201.3(b)(5) and 201.4(c)(7)).



*2018 State of Arizona Hazard Mitigation Plan*  
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If you have any questions please contact Juliette Hayes, Mitigation Division Director, at (510) 627-7211 or by email at [juliette.hayes@fema.dhs.gov](mailto:juliette.hayes@fema.dhs.gov).

Sincerely,



Robert Fenton  
Regional Administrator  
FEMA Region IX

Enclosure

cc: Susan Austin, Planning Branch Manager  
Lucrecia Hernandez, State Hazard Mitigation Officer

DEMA maintains the State of Arizona Hazard Mitigation Plan as a living document intended to be continuously reviewed and revised, with input from stakeholders, to guarantee the most current plan possible.

PLAN REVIEW AND EVALUATION			
Date	Summary of Activity	Plan Section	Recommendation By Entry Made By



DEMA is committed to ongoing training and engagement related to the State of Arizona Hazard Mitigation Plan to enhance hazard awareness and increase plan implementation.

TRAINING AND ENGAGEMENT ACTIVITY			
Date	Summary of Activity	Partners Involved	Entry Made By

The State of Arizona follows the 2016 EMAP Standard to ensure a quality program. Arizona was first accredited in 2004, and was reaccredited in 2009 and 2015.



<b>EMERGENCY MANAGEMENT ACCREDITATION PROGRAM (EMAP)</b>	
<b>EMAP Standard</b>	<b>Standard Component</b>
<b>4.1</b>	<b>Hazard Identification, Risk Assessment and Consequence Analysis</b>
4.1.1	The Emergency Management Program identifies the natural and human-caused hazards that potentially impact the jurisdiction using multiple sources. The Emergency Management Program assesses the risk and vulnerability of people, property, the environment, and its own operations from these hazards.
4.1.2	The Emergency Management Program conducts a consequence analysis for the hazards identified in Standard 4.1.1 to consider the impact on the following:
	(1) purpose and scope or goals and objectives
	(2) authority
	(3) situation and assumptions
	(4) property, facilities, and infrastructure
	(5) environment
	(6) economic condition of the jurisdiction
4.1.3	(7) public confidence in the jurisdiction's governance
	The Emergency Management Program has a method and schedule for evaluation, maintenance, and revision of its Hazard Identification, Risk Assessment (HIRA) and Consequence Analysis identified in Standard 4.1.1.
<b>4.2</b>	<b>Hazard Mitigation</b>
4.2.1	The Emergency Management Program has a plan to implement mitigation projects and sets priorities based upon loss reduction. The plan:
	(1) is based on the natural and human-caused hazards identified in Standard 4.1.1 and the risk and consequences of those hazards.
	(2) is developed through formal planning processes involving Emergency Management Program stakeholders.
4.2.3	(3) establishes interim and long-term strategies, measures, goals and objectives.
	The Emergency Management Program has a process to monitor overall progress of the mitigation activities and documents completed initiatives and their resulting reduction or limitation of hazard impact on the jurisdiction.
4.2.4	The Emergency Management Program, consistent with the scope of the mitigation



EMERGENCY MANAGEMENT ACCREDITATION PROGRAM (EMAP)	
EMAP Standard	Standard Component
	program, does the following:
	(1) provides technical assistance in implementing applicable mitigation codes and ordinances
	(2) identifies ongoing opportunities and tracks repetitive loss
	(3) participates in applicable jurisdictional, inter-jurisdictional and multi-jurisdictional mitigation efforts
4.2.5	The Emergency Management Program has a method and schedule for evaluation, maintenance, and revision of the plan identified in Standard 4.2.1.

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## SECTION 1: INTRODUCTION

### INTRODUCTION

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Hazards, exacerbated by climate change, have the potential of creating disasters that endanger the well-being of the entire community. The State of Arizona houses a culturally diverse population of approximately 6.9 million people, and hazards, if unabated, put every resident at risk. Hazard mitigation is a tactic that reduces or eliminates the impact hazards have on the community by reducing risk and vulnerability. In the context of this Plan, mitigation is a long-term solution to hazards and disasters that can prevent the disruption of a community's daily activities, reduce property damage, and save lives. The 2018 Plan identifies 15 hazards that pose a threat to the communities throughout the state. The Plan presents a strategy that has the potential to reduce or eliminate the risks and vulnerabilities associated with the identified hazards. The Plan, with the utilization of a community wide approach that fosters horizontal and vertical integration, can assist the State of Arizona in strengthening resilience and the ability to recover when disasters occur.

### WHAT IS HAZARD MITIGATION?

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The first step to understanding the State of Arizona Hazard Mitigation Plan is to understand what hazard mitigation is. Hazard mitigation is defined as any action taken to reduce or eliminate the long term risk to human life and property from human-caused or natural hazards. A hazard is any event or condition with the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural loss, environmental damage, business interruption, or other structural and financial loss. As communities continue to grow, hazard mitigation will play an even more important role in the government's primary objective of protecting its citizens' health, safety, and welfare.

Hazard mitigation aims to make human development and the natural environment safer and more resilient. Hazard mitigation generally involves altering the built environment to significantly reduce risks and vulnerability to hazards so that life and property losses can be avoided or reduced. Mitigation can also include removing the built environment from disaster prone areas and maintaining natural mitigating features, such as wetlands or floodplains. Hazard mitigation makes it easier and less expensive to respond to and recover from disasters by breaking the damage and repair cycle.

Examples of hazard mitigation measures include, but are not limited to the following:

- Development of mitigation standards, regulations, policies, and programs
- Land use/zoning policies
- Strong statewide building code and floodplain management regulations
- Dam safety program, seawalls, and levee systems
- Acquisition of flood prone and environmentally sensitive lands
- Retrofitting/hardening/elevating structures and critical facilities



- Relocation of structures, infrastructure, and facilities out of vulnerable areas
- Public awareness/education campaigns

Benefits of hazard mitigation include:

- Saving lives and protecting public health
- Preventing or minimizing property damage
- Minimizing social dislocation and stress
- Reducing economic losses
- Protecting and preserving infrastructure
- Less expenditures on response and recovery efforts

The National Institute of Building Sciences issued the *Natural Hazard Mitigation Save: 2017 Interim Report*. The report project team looked at the results of 23 years of federally funded mitigation grants provided by the Federal Emergency Management Agency (FEMA), US Economic Development Administration and US Dept of Housing and Urban Development (HUD) and found mitigation funding **can save the nation \$6 in future disaster costs, for every \$1 spent** on hazard mitigation.

In addition, the project team looked at scenarios that focus on designing new buildings to exceed provisions of the 2015 model building codes. The report also demonstrates that investing in hazard mitigation measures to exceed select requirements of the *2015 International Codes*, the model building codes developed by the International Code Council, can save the nation \$4 for every \$1 spent.

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## PLAN PURPOSE

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The 2018 Plan identifies risks and presents mitigation measures that can prevent hazards from becoming disasters. Natural and human-caused disasters create many problems that can affect entire populations for long periods of time. Mitigation measures have the potential to save lives, prevent injury, reduce property damage, prevent community and economic disruption, protect the environment, and reduce the costs associated with disaster assistance. The Plan is public record and serves as a source of information for all levels of government, the private and non-profit sectors, and individuals in the community.

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## AUTHORITY

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Meeting the requirements of Section 322 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act or the Act), 42 USC. 5165, enacted under Sec. 104 the Disaster Mitigation Act of 2000, (DMA 2000) Public Law 106-390 of October 30, 2000, keeps the State of Arizona eligible to apply for disaster assistance, including hazard mitigation grants, available through the Robert T. Stafford Disaster Relief and Emergency Assistance Act, P.L. 93-288, as amended.

The Plan was prepared by the Arizona Department of Emergency Management and Military Affairs (DEMA), Division of Emergency Management. Arizona Revised Statutes (ARS) 26-305 establishes DEMA via the following:

A. There is established in the Department of Emergency and Military Affairs the Division of Emergency Management which is administered by the department, under the authority of the Adjutant General, subject to powers vested in the Governor as provided by law.

The section goes on to designate DEMA as the State of Arizona entity responsible for emergency preparedness, including mitigation, via the following:

B. The division shall prepare for and coordinate those emergency management activities which may be required to reduce the impact of disaster on persons or property.

C. Through the powers vested in the Governor, the division shall coordinate the cooperative effort of all governmental agencies including the Federal Government, this state, and its political subdivisions to alleviate suffering and loss resulting from disaster.

## **ASSURANCES**

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This Plan will comply with all applicable federal statutes and regulations in effect with respect to the periods for which it receives grant funding, in compliance with 44 CFR 13.11 (c), and will amend its plan whenever necessary to reflect changes in state or federal laws and statutes as required in 44 CFR 13.11 (d).

## SECTION 2: STATE OVERVIEW

### SECTION CHANGES

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This section is redesigned to describe the state in operational regions rather than counties.

### GEOGRAPHY

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#### **Ecological Regions**

Arizona's ecological regions (ecoregions) vary across the state due to vast differences in elevation. Arizona has an elevation of 12,633 ft at its highest point and 70 ft at its lowest. Ecoregions can be defined as areas of water or land with similar environmental conditions and biological communities. The Plan utilizes the Level I Ecoregion Classification System from the US Environmental Protection Agency. The Level I Classification System was selected in order to provide a broad overview of the main ecological regions in the State of Arizona. The North American Deserts, Southern Semi-Arid Highlands, and Temperate Sierras are the three broad ecoregions located within Arizona (see Map 1).

#### **North American Deserts Ecoregion**

The North American Deserts ecoregion is made up of four deserts: the Mojave Desert, the Great Basin Desert, the Chihuahuan Desert, and the Sonoran Desert. The Mojave Desert covers a small portion of the northwest corner of the state and is characterized by a rainy winter season with hard freezes. Vegetation in the Mojave Desert consists of low shrubs, *Yucca brevifolia* (Joshua tree), arborescent yucca, and annual flowers that are known to bloom during wet years. The Great Basin Desert is located in the northernmost region of the state and is known for its very cold winters. Vegetation lies dormant during the cold winters, limiting plant growth to the summer season. The vegetation consists of low, small-leaved shrubs. There are no trees or cacti in the Great Basin Desert, and the environment is often dominated by *Artemisia tridentata* (sagebrush). The Chihuahuan Desert is located in the southeastern corner of the state at a higher elevation than the other three deserts. The vegetation consists of varying species of low shrubs, succulents, small cacti, and few trees. Precipitation is predominantly in the summer, but winter rain at the northern end of the desert can cause a springtime bloom of annual flowers. The Sonoran Desert is the largest desert in Arizona and encompasses most of the southern half of the state. The Sonoran Desert also houses the majority of the state's population, along with over 2,000 plant species and nearly 550 species of vertebrates. Mild winters allow for trees, grasses, cacti, shrubs, and wildflowers to persist and stay in season year round.

#### **Southern Semi-Arid Highlands Ecoregion**

The Southern Semi-Arid Highlands ecoregion is located at the southeastern corner of Arizona where the Sonoran and Chihuahuan Deserts intersect. Natural vegetation varies and is dependent on elevation, but the ecoregion is relatively high in plant and animal diversity. Low elevation areas consist of desert grassland and desert scrub, while oak and juniper trees are abundant in areas with intermediate elevation. Trees that grow needles

instead of leaves and cones instead of flowers form coniferous forests at the highest elevations within the ecoregion. The ecoregion is diverse with mountains of volcanic origin and with valleys and plains that are coated in alluvial sediment.

### **Temperate Sierras Ecoregion**

The Temperate Sierras ecoregion is a montane forest that is surrounded by lower elevations of arid and semi-arid deserts. In Arizona, the ecoregion is flanked by deserts with the Great Basin Desert to the north/northeast, the Mojave Desert to the west, the Sonoran Desert to the south/southwest, and the Southern Semi-Arid Highlands ecoregion to the southeast. The ecoregion's vegetation is primarily comprised of conifers and oak trees that can grow up to 164 feet in height.

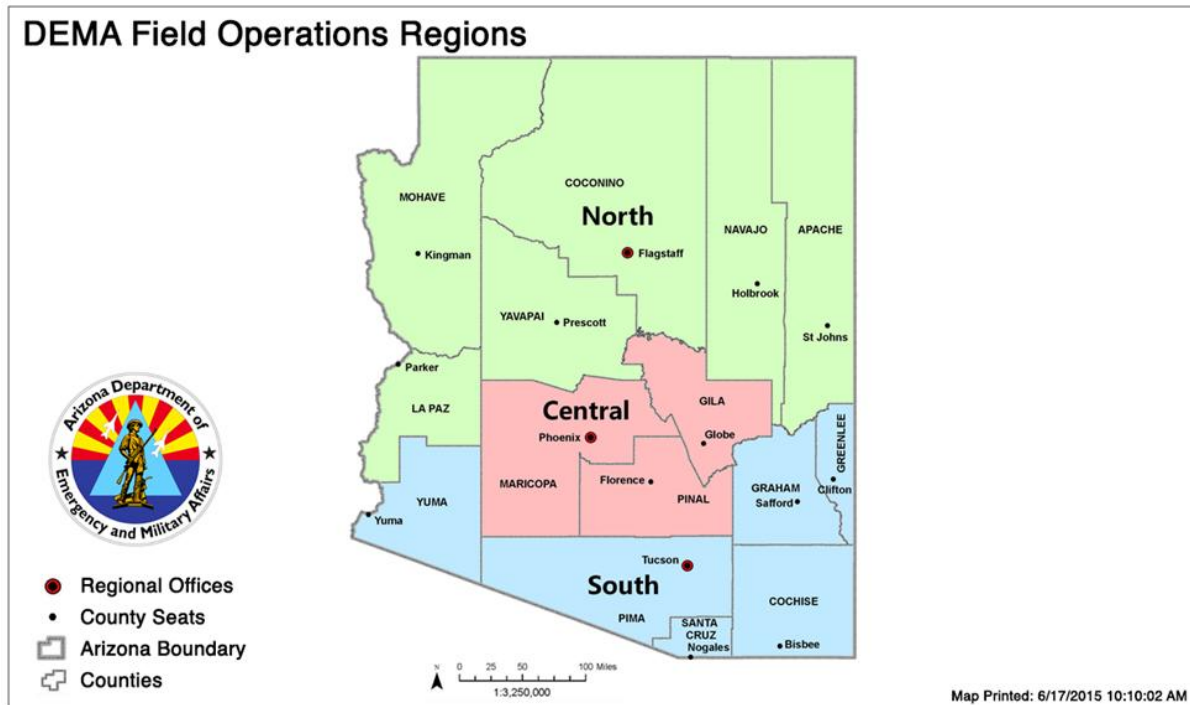
## **OPERATIONAL REGIONS**

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County and tribal information will not be independently presented within the Plan. Information from approved county and tribal hazard mitigation plans will be consolidated and presented as operational regions as described below.

DEMA has divided Arizona's 15 counties into three operational regions in order to pursue a Whole Community approach that best serves the residents of the state by ensuring continuity between and amongst all counties and Tribal Nations. The three operational regions are designated as North, Central, and South, and each region is represented by a DEMA Field Coordinator. The Field Coordinators serve as liaisons and provide technical assistance to county and tribal emergency managers and assist with coordinating response and recovery/mitigation measures during and after emergencies or disasters. The Field Coordinators also serve as liaisons between DEMA and other local, county, state, and federal agencies. The operational regions are not defined by any ecological boundaries but they each have unique characteristics.



**Map 1: DEMA Field Operations Regions**

### North Region

The North Region has the largest land mass of the three operational regions and consists of six counties and 11 sovereign Tribal Nations (note that some of the sovereign Tribal Nations in the North Region transcend the boundaries of operational regions). The North Region is the home of the Grand Canyon and the City of Flagstaff. The region is located at the highest elevation in Arizona and is made up of the North American Deserts and the Temperate Sierras ecoregions.

### Central Region

Housing the Phoenix Metropolitan area, the Central Region is the population center of the State of Arizona and consists of three counties and eight sovereign Tribal Nations (note that some of the sovereign Tribal Nations in the Central region transcend the boundaries of operational regions). The North American Deserts ecoregion makes up most of the Central Region's geography. However, the northeast portion of the region is in the Temperate Sierras ecoregion, and the southeast corner of the region is in the Southern Semi-Arid Highlands ecoregion.

### South Region

The South Region has unique characteristics as it spans the width of the state and borders the country of Mexico. The region consists of six counties and five sovereign Tribal Nations (note that some of the sovereign Tribal Nations in the South region transcend the boundaries of operational regions and the US - Mexico border). The South Region is the home of Tucson and has a split geography that consists of the North American Deserts ecoregion to the west and the Southern Semi-Arid Highlands ecoregion to the east.

## NATIVE AMERICAN TRIBES IN ARIZONA

Arizona is a culturally diverse state and home to 22 federally recognized sovereign Native American tribes. These Native American tribes include:

- Ak-Chin Indian Community
- Cocopah Tribe
- Colorado River Indian Tribes
- Fort McDowell Yavapai Nation
- Fort Yuma-Quechan Tribe
- Gila River Indian Community
- Gila River Indian Community
- Havasupai Tribe
- Hualapai Tribe
- Hopi Tribe
- Kaibab-Paiute Tribe
- Navajo Nation
- Pascua Yaqui Tribe
- Salt River Pima-Maricopa Indian Community
- San Carlos Apache Tribe
- San Juan Southern Paiute Tribe
- Tohono O’odham Nation
- Tonto Apache Tribe
- White Mountain Apache Tribe
- Yavapai-Apache Nation
- Yavapai Prescott Indian Tribe
- Zuni Tribe



Tribal Nations have shaped Arizona and its culture in many ways - even the name Arizona comes from the Papago word, Airzonac, which means “small springs.” Native American art, designs, and styles have strongly influenced Arizona architecture and can be seen across the state. Arizona’s strong agriculture ties (the state has more than 20,000 farms and ranches) relate back to the agricultural roots established by the tribes and are based on the well-developed irrigation systems that they built over a thousand years ago. Today, the majority of newly reported farms and ranches come from tribal lands.

Many counties (Apache, Coconino, Gila, Maricopa, Mohave, Navajo, Pima, Yavapai, and Yuma) are named after various Native American tribes that make up the state. One county, Cochise County, is named after the great Chiricahua Apache chief who led an uprising against the US government, which began in 1861 and persisted until a peace treaty was reached in 1872. Even cities such as Tucson and Yuma take their names from the Native American tribal languages.

In the lower 48 states, the entire land mass of the tribal lands covers over 56 million acres, or nearly 5% of the total land area of the United States. Tribal land in Arizona totals more than 20,000,000 acres, or approximately 43,300 square miles - about 27% of all land within the state. This means that over a third of all tribal lands in the lower 48 states are found in Arizona, including the largest tribal reservation, the Navajo Nation. At approximately 25,000 square miles, the Navajo Nation is roughly the size of the state of West Virginia.

Approximately 300,000 people in Arizona are Native American, which makes up over 4% of the state’s population. Of that, over 252,000 individuals still live on tribal reservation land. That makes Arizona home to six of the top 20 most populated tribal reservations, including the Navajo Nation, the White Mountain Apache Tribe of the Fort Apache Reservation, the Gila River Indian Community, the San Carlos Apache Tribe, the Tohono O’odham Nation, and the Hopi Tribe.

Tribal Nations possess a sovereign nation status that allows them to have a direct government-to-government relationship with the Federal Government. In spite of this, Arizona tribes regularly plan and prepare with the state and their neighboring jurisdictions.

As a result of their sovereign status, Tribal Nation governments have constitutions, articles of association and other bodies of law, are able to make laws governing the conduct of persons (including non-Indians) on their lands, establish bodies such as tribal police and courts, exclude or remove non-members from their lands, regulate hunting, fishing, and land use, establish taxes for items purchased on tribal lands, and establish environmental protections.

Tribal economic bases can vary greatly from tribe to tribe. Some tribal enterprises include commercial endeavors like agriculture and timber. The most well-known tribal enterprise is tribal gaming, but not all tribes have casinos. The largest component of many tribal economies is tourism. The more well-known tourism opportunities include staying in one of the many tribal resorts across the state, visiting one of the many tribal shopping centers, attending events at a tribal entertainment arena, or even watching a Spring Training game at the Salt River Fields on the Salt River Pima-Maricopa Indian Community. There are many other unique opportunities offered as well, including staying in campgrounds at the bottom of the Grand Canyon with the Havasupai, traveling the Hopi Arts Trail to connect with artists and galleries on the Hopi mesas, or visiting the Skywalk on the Hualapai reservation at Grand Canyon West. All of these enterprises bring thousands of tourists to tribal lands and Arizona throughout the year.

As Arizona tribes continue to increase their self-governance, some have taken over the administration of their educational institutions, law enforcement, healthcare, and maintenance of

infrastructure while others rely upon various federal agencies to provide these services. This means that planning and working with our tribal partners often includes various federal entities as well.

## **CLIMATE**

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The climate varies across the State of Arizona and is dependent upon the level of elevation. Elevation is not the only factor that influences the climate in today's world as the ever evolving environment has become an area of focus that must be considered in order to successfully mitigate disasters. Climate change demands attention as hazards can potentially increase in frequency and intensity, and pose a greater risk to Arizona. Future conditions are unknown, but the climate trend shows an increase in the average temperature throughout the State of Arizona.

### **Temperature and Precipitation**

Arizona experiences biannual precipitation during both summer and winter months. Winter precipitation occurs from November through March, and the frequency of rainfall has been known to cause heavy snow in the North and Central regions. Summer rainfall occurs from July through September, and the combination of precipitation and high temperatures gives way to Arizona's monsoon season. Monsoon season in Arizona is characterized by thunderstorms with heavy rain, high winds, and lightning that can cause flash flooding, dust storms, and wildfires.

#### **North Region**

The North Region has the highest elevation of three regions, with the vast majority of the region resting at an elevation between 5,000-8,000 ft and mountainous peaks reaching above 12,000 ft. The easternmost and southeastern most portions of the region drop to an below 5,000 ft to a low point of approximately 160 ft. The high elevation creates a climate lower in temperature and higher in precipitation when compared to the Central and South regions of the state. The average yearly maximum and minimum temperatures for the region are 74.5 and 39.1°F, and areas of the North Region have been known to reach temperatures below freezing point with the potential of dropping below zero during winter months. The North Region receives the highest amount of precipitation in the state with some areas receiving as much as 35-40 inches of rain per year.

#### **Central Region**

The Central Region rests at an elevation between 1,000-5,000 ft with small portions of the northeast ranging between 5,000-8,000 ft and small portions of the southwest dropping to an elevation of 425 ft. Temperatures in the region have an average yearly maximum of 86.5°F and a minimum of 62.4°F, but the temperature has been recorded as reaching above 120°F during the summer months. The Central Region houses the Phoenix Metropolitan area which consists of approximately 4.63 million people. The elevation, along with population density and the built environment, have lead to significant temperature increases in the area. The Phoenix Metropolitan area receives an annual five to 10 inches of rain, while the more mountainous portions of the region in the north receive as much as 30 inches per year.

## South Region

The majority of the South Region rests at an elevation between 1,000-5,000 ft with small eastern portions of the region reaching above 8,000 ft and small western portions of the region reaching below 1,000 ft to a low point of 70 feet. The average yearly maximum and minimum temperature of the entire region is 82.8 and 52.8°F with areas of higher elevation in the east having a cooler climate than the rest of the region. Precipitation in the region coincides with the elevation as the eastern portion of the region receives an annual 10-30 inches of rain while the western portion receives .01-10 inches of rain per year.

## DEMOGRAPHICS

*\*All demographic statistics are based on 2015 and 2016 United States Census Bureau estimates.*

The demographics of Arizona will be presented in a manner that highlights vulnerable populations, as social vulnerability is a concern that must be addressed throughout all phases of emergency management. Various population groups have different capacities, capabilities, concerns, and needs, all of which need to be considered in order to promote mitigation and create resilient communities. There are many different categories of vulnerable populations, but this Plan will only discuss the vulnerable populations of elderly above the age of 65, children below the age of 18, those living in poverty, and individuals with limited English proficiency.

Arizona is ranked as the thirteenth most populous state and is one of the fastest growing in terms of both numeric and percentage population growth. Arizona's population has grown by 8.4% between 2010-2016, and as of 2016 the population reached approximately 6.93 million. The growth rate can be partly attributed to an increased birth rate and Arizona being a retirement state. Arizona has an elderly population (65+) of 16.9% and an under the age of eighteen population of 23.8%. 24.7% of the under the age of eighteen population and 17.4% of the state's population currently live in poverty.

The unique location of Arizona has created diversity resulting in demographics that deviate from the national averages. An African American/Black population of 4.9%, a White/Caucasian population of 55.5%, and an Asian population of 2.8% are all lower than their national averages of 13.3%, 61.3%, and 5.7% respectively. The State of Arizona is unique as it houses 22 sovereign Tribal Nations and borders the country of Mexico, both of which contribute to an increased prevalence of Hispanic/Latino and Native American population groups. Arizona's 30.9% Hispanic/Latino population and 5.4% Native American population are both significantly higher than their national averages of 17.8% and 1.3% respectively.

## North Region

The North Region has a growth rate of approximately 4% and currently houses 11.18% of the state's population with 775,174 residents. The North Region is the smallest in terms of population size but has the highest population concentrations of White/Caucasians (63.1%), Native Americans (20.6%), elderly (23.2%), and individuals living in poverty (20.7%). Conversely, the North Region has the lowest population concentrations of Black/African Americans (1.1%), Hispanic/Latinos (13.8%), Asians (1.14%), and individuals under the age of eighteen (20.5%).



## Central Region

The Central Region has a growth rate of approximately 11% and currently houses 68.03% of the state's population with 4,715,093 residents. The fast growth rate can be observed, in part, by a high concentration of individuals under the age of eighteen (24.4%) and a low concentration of elderly (15.2%) persons. The Central Region represents the majority of the population, and the population concentrations of the region are similar to that of the state's overall demographics. The region has the lowest poverty rate (16.3%) with a population that consists of 56.3% White/Caucasian, 5.9% Black/African American, 30.5 % Hispanic/Latino, 3.3% Native American, and 4.6% Asian.

## South Region

The South Region has a growth rate of approximately 2.9% and currently houses 20.79% of the state's population with 1,440,804 residents. The region has a unique demographic as the minority groups are the majority and make up 52.3% of the population. The region has a poverty rate of 19.1% with a population that consists of 48.6% White/Caucasian, 3.8% Black/African American, 41.8% Hispanic/Latino, 4% Native American, and 2.7% Asian. The region has an 18.9% elderly population and a 22.4% population of individuals below the age of eighteen.

## ECONOMY

Gross domestic product (GDP) is the monetary value of goods and services produced in a country's or state's borders in a specific time frame. GDP includes all private and public consumption, private inventories, government outlays, investments, paid-in construction costs, and the balance of exports and imports. Arizona's GDP is \$305.8 billion in 2016 and is ranked 21<sup>st</sup> among all states. In 2016 the top five industries were, in order, (1) finance, insurance, real estate, rental and leasing; (2) government; (3) professional and business services; (4) educational services, health care, and social assistance; and (5) retail trade.

The housing market and employment rates are also indicators of economic health. These aspects are discussed on a regional basis, with a focus on the largest population center for each region.

## North Region

In 2016, Flagstaff saw the nonfarm payroll jobs increased by 700, or 1.1%, to 66,100 jobs. This is the first time nonfarm payroll jobs have surpassed prerecession highs of 65,600 jobs in 2007. Additionally, the employment rate in Flagstaff dropped to 6.6% in 2016 and continues to decline. The sales housing market conditions are considered soft with a 2016 vacancy rate of 2.9% and housing demands are expected to increase in the coming years. The current and future vacancies will satisfy the projected housing demand increase.

## Central Region

The nonfarm payroll jobs of Phoenix, Scottsdale, and Mesa increased by 63,800, or 3.4%, to 1.93 million in 2016. The unemployment rate for the same three cities in the Central Region decreased from 5.7% to 5.1% and continues to decline. The sales housing market was considered slightly soft with a vacancy rate decrease from 4.3% to 2.9%. Housing demands are expected to increase in the future to more than 72,000 unit sales. In 2016, there were approximately 3,600 units under construction, which will help accommodate the increased housing demand.

## South Region

Tucson saw the nonfarm payroll job increase by 4,800, or 1.3%, to 370,700 jobs. Nonfarm payroll jobs still remain below the prerecession high of 385,600 jobs in 2007. The unemployment rate in Tucson dropped to 5.3% in 2016 and continues to decline. The sales housing market conditions are soft with an estimate vacancy rate of 2.8%, down from the previous year's 2.9%. Home sales increased by approximately 11% to 17,400 from 2015-2016, and the housing demand is projected to increase.

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## SECTION 3: PLANNING PROCESS

### PLANNING TEAM AND ACTIVITIES

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The planning effort for the 2018 Plan update began in 2016 when DEMA submitted for Pre-Disaster Mitigation (PDM) grant funding to hire a contractor to complete the risk assessment portion of the Plan. DEMA was awarded a PDM grant in early 2017, and contractors were interviewed May 1<sup>st</sup> of the same year. A contract was awarded to JE Fuller in May 2017 with a project contract completion date of November 2018. The entire update process for this Plan took over a year, with the first in-person planning team meeting being held in June 2017 and the last in March 2018.

For this Plan update, DEMA created a core planning team that consisted of the DEMA Planning Branch and JE Fuller, and an extended planning team (planning team) that consisted of the core planning team along with various SMEs. The core planning team was responsible for the overall design and development of this Plan while the SMEs served as decision makers and provided information that formed and guided the development of the hazard profiles and mitigation strategy. The core planning team communicated with SMEs via phone and email to obtain hazard information regarding the history, location, extent/severity, future conditions, and how to most effectively map the hazards. For example, the Arizona Geological Survey (AZGS) was one of the SMEs on the planning team who provided information to develop the earthquake, fissure, landslide, and subsidence hazard profiles. Multiple in-person planning team meetings were held to discuss and gain consensus on the vision of this Plan, potential changes, and the importance of having a plan that can increase resiliency through the reduction and/or elimination of a hazard's impacts.

The core planning team worked on one hazard at a time, gathering information and data from SMEs and other sources to compile a hazard profile. The compiled hazard profile was first reviewed by the DEMA Planning Branch for completeness and accuracy before being sent to the SMEs for review and approval. The SMEs would make edits and recommendations to the core planning team and the hazard profiles would be altered accordingly. After all hazard profiles were completed, the entire risk assessment was reviewed by the planning team to ensure accuracy and completeness, and to make last minute changes.

The DEMA Planning Branch staff led the planning effort to review, update, and redesign this Plan. DEMA recognizes the importance and necessity of building a planning team that consists of a variety of stakeholders and subject matter experts from different sectors. For the Plan update, DEMA sent out email invitations to stakeholders statewide requesting their participation in the planning process. This included, but was not limited to, the DEMA Non-governmental Organization and Private Sector Liaison, the AZ Department of Transportation, the AZ Department of Economic Security, the AZ Department of Administration, the AZ Department of Land, the AZ Department of Health, the DEMA Tribal Liaison, the AZ Department of Environmental Quality, and the DEMA Infrastructure Coordinator. However, not all invitees were able to participate in the planning effort for various reasons, including, limited staff and schedule availability.

Although the listed planning team participants for this Plan update is limited, the overall breadth and depth of the planning team was extensive. The identified SMEs served as representatives of

their respective agencies and they often collaborated with other members of their agencies to make collective decisions, and to gather and provide the most accurate information. This process resulted in a structure that branched out and formed a planning team network that was extensive, and encompassed a wide variety of participants.

The planning team consisted of the following individuals (returning members are in **bold** text):

Name	Agency/Organization	Roles/Responsibilities
<b>Nancy Selover</b>	AZ State University Climate Office	Future Conditions
Nalini Chhetri	AZ State University Climate Office	Future Conditions
<b>Brian Cosson</b>	AZ Dept of Water Resources	Dam/Levee/Flood Profiles, & NFIP/CRS/RL/SRL Info
Mike Shelton	AZ Dept of Water Resources	Dam/Levee/Flood Profiles, & NFIP/CRS/RL/SRL Info
	AZ Geological Survey	Earthquake/Fissure/Landslide/Subsidence Profiles
Antonio Hernandez	AZ Dept of Health Services	Vulnerable Populations & Infectious Diseases Profile
Corey Tarango	AZ Dept of Health Services	Vulnerable Populations & Infectious Diseases Profile
John Danovich	AZ Dept of Agriculture	Agricultural Economic Impacts
Marvin Perda Jr.	National Weather Service	Severe Wind/Winter Storm/Drought/Flood Profiles
Jessica Nolte	National Weather Service	Severe Wind/Winter Storm/Drought/Flood Profiles
<b>Susan Austin</b>	AZ Dept of Emergency & Military Affairs	Plan Reviewer & Editor
Nicholas Mazzone	AZ Dept of Emergency & Military Affairs	Plan Coordinator/Designer/Author/Reviewer/Editor
Travis Icard	AZ Dept of Emergency & Military Affairs	HAZMAT & Terrorism Profiles
Wes Dison	AZ Dept of Emergency & Military Affairs	Plan Reviewer & Editor
Whitney Hensiak	AZ Dept of Emergency & Military Affairs	Critical Infrastructure & Non-Governmental Organizations/Private Partner Liaison
Erik Lohman	AZ Department of Administration	State Owned Facilities
Owen Zorge	AZ Department of Administration	Terrorism Profile
Robert Barnett	AZ Department of Environmental Quality	HAZMAT & Terrorism Profiles
Shawn Kendal	AZ Department of Environmental Quality	HAZMAT & Terrorism Profiles
Alcira Angulo	AZ Department of Economic Security	Vulnerable Populations
Fred Breedlove	AZ Department of Land	Wildfire Profile & State Land Information
Ilene Klein	AZ Counter Terrorism Information Center	Terrorism Profile
Scott Ogden	JE Fuller	Hired Contactor-Risk Assessment

<b>Name</b>	<b>Agency/Organization</b>	<b>Roles/Responsibilities</b>
Matt Heckard	AZ Dept of Emergency and Military Affairs	Plan Reviewer & Editor
Ashleigh Makuch	AZ Dept of Emergency and Military Affairs	Plan Reviewer & Editor
Joe Urrea	AZ Dept of Emergency and Military Affairs	Tribal Information
Lucrecia Hernandez	AZ Dept of Emergency and Military Affairs	Hazard Mitigation Assistance Grants & State Mitigation Program
Duke Jones	AZ Dept of Emergency and Military Affairs	Hazard Mitigation Assistance Grants & Public Assistance Grants



## SECTION 4: RISK ASSESSMENT

### SECTION CHANGES

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- Historic disaster declaration specific data was omitted and can be found in the ‘History’ section of each hazard profile.
- Information is now presented on a regional level using three areas (North, Central, and South) that are designated as regional preparedness areas.
- Data tables have primarily been omitted and replaced with narrative and snapshot tables on maps.
- The risk assessment includes climate change and changing development conditions in each hazard profile where appropriate.
- The Plan now evaluates more categories of vulnerable populations to include age, federal poverty level, and language.
- The Calculated Priority Risk Index (CPRI) is no longer used. Information related to levels of probability, magnitude, and warning time are now found in narrative form.

### OVERVIEW

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The purpose of the risk assessment is to identify and characterize Arizona’s hazards, determine which regions are most vulnerable to each hazard, and estimate potential losses to vulnerable state facilities from those hazards. Elements of the risk assessment are generally summarized in the following sections.

### HAZARD IDENTIFICATION

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#### General

The hazards identified in the 2013 Plan were closely examined and screened by the Planning Team. Certain considerations used by the Planning Team should be highlighted prior to reviewing risk assessment data in this section. These considerations include:

- Prior knowledge of the relative risk associated with each of the hazards;
- Information from the hazard event datasets, including any recent events occurring within the current plan update cycle;
- Comparison to risk assessment outcomes identified in local jurisdiction plans;
- The ability to effectively mitigate the hazard;
- The known or expected availability of information on the identified hazard;
- Duplication of the hazard’s risk in other hazard definitions; and
- Whether or not the hazard is already being sufficiently addressed through other planning efforts of the state.

## Profiled Hazards

The Planning Team reviewed the 2013 State Plan hazards, as well as the profiles and historic hazard events summarized in each of the 15 county hazard mitigation plans, to develop the list of hazards profiled and assessed in this Plan. The county plan data provides information from a local perspective that aids in identifying and screening hazards to determine statewide risk. The presumption is that the importance given to hazards by local communities can inform the prioritization of hazards at the state level. According to the county plans, the top hazards predominately and consistently identified were:

- Drought
- Severe Wind
- Flooding
- Wildfires

The following list of hazards represents the result of the review and screening/identification process undertaken by the Planning Team. Each of these hazards is addressed in the profiling and vulnerability assessment phases of the overall risk assessment for this Plan. The top four hazards taken from the county plans are supportive of the hazards the Planning Team determined as the most important statewide:

- Dam Failure
- Landslide
- Drought
- Levee Failure
- Earthquake
- Severe Wind
- Extreme Heat
- Subsidence
- Fissure
- Terrorism
- Flooding
- Wildfires
- Hazardous Materials Incidents
- Winter Storm
- Infectious Disease

## CLIMATIC EFFECTS

FEMA issued new state mitigation planning guidance in March 2015 that required all state hazard mitigation plans to address climate change as part of plan updates starting in March of 2016<sup>1</sup>. FEMA's National Advisory Council noted that the effects of climate change could manifest as a "threat multiplier." It is typical when looking at potential exposure to hazard events to look at the past probability of the event occurrence as a predictor of the future risk. However, climate-related trends may affect these future event probabilities and the effectiveness of mitigation measures.

While the scope and severity of these climate-related impacts is difficult to predict, scientific research has pointed to several important trends that should be considered as part of a natural hazard vulnerability and risk analysis. In 1989, the US Global Change Research Program (USGCRP) was established by Presidential Initiative and later mandated by Congress in the

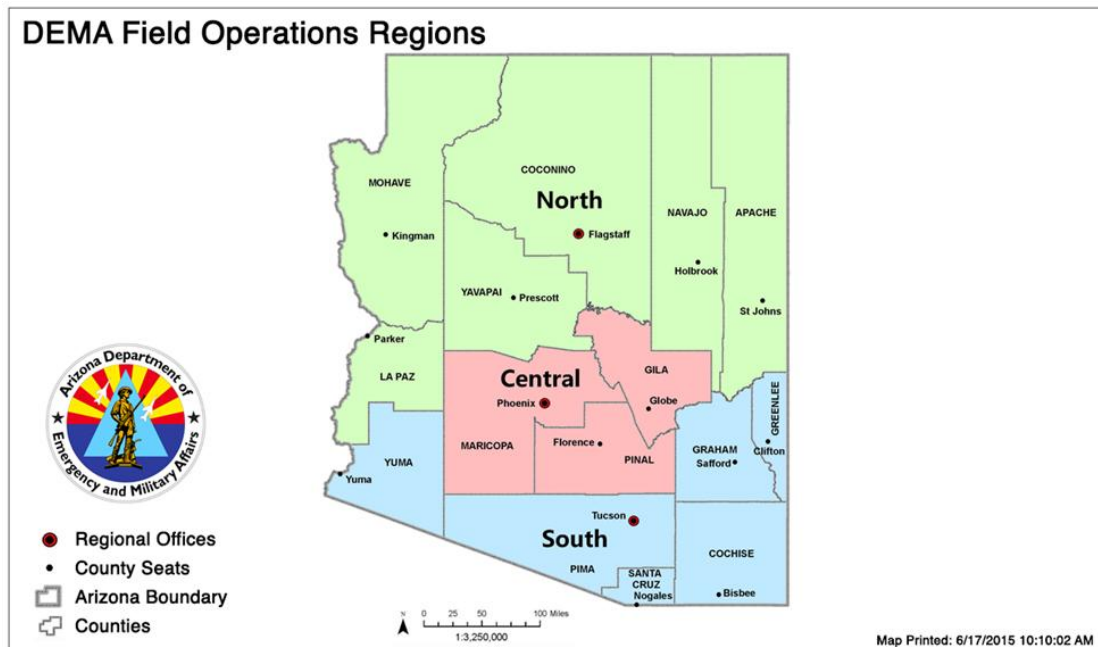
<sup>1</sup> FEMA, 2015, State Mitigation Plan Review Guide, FP 302-094-2

Global Change Research Act of 1990 with the stated purpose of assisting “the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.” In May 2014, the USGCRP released the 3rd National Climate Assessment (NCA), which is a comprehensive compilation of the latest body of work and science on the topic of climate change. The NCA results and discussion are divided into regions to focus the discussions and conclusions to a regional perspective. The Southwest region includes the states of Arizona, California, Colorado, Nevada, New Mexico, and Utah. According to Chapter 20 of the NCA<sup>1</sup>, the Southwest regional climate change impacts noted in the recent research include increased heat, drought, and insect outbreaks that result in more wildfires, declining water supplies, reduced agricultural yields, health impacts in cities due to heat, and flooding and erosion in coastal areas.

## ARIZONA REGIONS

A new feature of this Plan is the summary and presentation of vulnerability and risk at a regional level. The regional boundaries are based on DEMA’s Field Operations Regions, with each hazard profile characterizing the specific vulnerabilities and impacts of each hazard in these three regions.

- **North Region** – Apache, Coconino, La Paz, Mohave, Navajo, and Yavapai Counties
- **Central Region**- Gila, Maricopa, and Pinal Counties
- **South Region**- Cochise, Graham, Greenlee, Pima, Santa Cruz, and Yuma Counties



<sup>1</sup> Garfin, G., G. Franco, H. Blanco, A. Comrie, P. Gonzalez, T. Piechota, R. Smyth, and R. Waskom, 2014, Ch. 20: Southwest. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., USGlobal Change Research Program, 462-486. doi:10.7930/J08G8HMN

## ASSESSING VULNERABILITY

The statewide vulnerability assessment for each hazard detailed in this Plan has been updated to reflect new available data, including local hazard mitigation plan data that have become available over the last five years. Specific changes will be summarized in each of the hazard profiles.

The vulnerability assessment for this Plan update is comprised of three key components:

1. State Asset Inventory
2. State Loss Estimation
3. Local Vulnerability Summary

The procedures and methodology used by the Planning Team to accomplish each of these three components are discussed in the following subsections.

### State Asset Inventory

The following definition for the state's asset inventory is adopted by the Planning Team for this Plan update: *Any natural or human-caused feature that has value including, but not limited to people; buildings; infrastructure like bridges, roads, and sewer and water systems; lifelines like electricity and communication resources; or environmental, cultural, or recreational features like parks, dunes, wetlands, or landmarks.*

#### State-Owned Structural Assets

Critical facilities and infrastructure are those systems within the state whose incapacity or destruction would have a debilitating impact on the state's ability to recover following a major disaster, or to defend the people and structures of the state from further hazards. The seven general categories that define critical facilities and infrastructure for this plan are defined in Table 1.

**Table 1: Critical Facilities and Infrastructure Categories**

Asset Type	Description
Communications Infrastructure	<ul style="list-style-type: none"> <li>• Fiber optic lines</li> <li>• Radio, cellular, and microwave towers</li> <li>• Large, trunk-line cables, switch offices</li> </ul>
Electrical Power Systems	<ul style="list-style-type: none"> <li>• High voltage transmission lines</li> <li>• Transform substations, generation stations</li> </ul>
Gas and Oil Facilities	<ul style="list-style-type: none"> <li>• Conveyance or delivery pipelines</li> <li>• Major storage locations (10,000 gallons or larger)</li> <li>• Production facilities, refineries</li> <li>• Natural gas pipelines (4-inch and larger)</li> <li>• Fuel and oil dispensing locations owned by the state</li> </ul>

Asset Type	Description
Transportation Networks	<ul style="list-style-type: none"> <li>• Interstates, US or state highways, major local arterial roadways</li> <li>• Railways, rail yards, train depots</li> <li>• Airports</li> <li>• Major bridges, culverts, and storm drains that protect transportation infrastructure</li> </ul>
Water Supply Systems	<ul style="list-style-type: none"> <li>• Water treatment plants, sewer treatment plants, water supply wells/reservoirs</li> <li>• Primary delivery pipelines (10-inch and larger)</li> <li>• Booster or pump stations</li> <li>• Storage tanks, water towers</li> </ul>
Government Services	<ul style="list-style-type: none"> <li>• City, county, and state administrative buildings</li> <li>• Facility yards</li> <li>• Military bases, correctional facilities</li> <li>• Emergency operation centers, IT support centers</li> </ul>
Emergency Services	<ul style="list-style-type: none"> <li>• Fire, police, and sheriff stations</li> <li>• Hospitals, trauma or urgent care centers</li> <li>• Evacuation centers, ambulance centers</li> </ul>

State-owned structures and buildings compiled for the asset inventory were updated using a GIS database provided by the Arizona Department of Administration (ADOA). The Planning Team further parsed and attributed the ADOA data to categorize each facility into one of the types listed in Table 2 or as “other” facilities. A total of 3,797 critical structures and facilities were identified and are detailed by region in Table 2 below.

**Table 2: Critical Facilities and Infrastructure Statewide**

State Facility Type	North Region	Central Region	South Region	Total
Communications Infrastructure	29*	13	12	<b>54*</b>
Electrical Power Systems	2	14	0	<b>16</b>
Emergency Services	142	143	33	<b>318</b>
Gas and Oil Facilities	5	9	2	<b>16</b>
Government Services	1,065	1,581	650	<b>3,297</b>
Transportation Networks	33	51	21	<b>69</b>
Water Supply Systems	17	72	0	<b>26</b>
Other Facilities	693	1,680	787	<b>3,160</b>
* One facility is located outside the state boundary				

Replacement values for ADOA facilities were either assigned directly from the original ADOA data or calculated using the facility's building size estimate and an assumed unit replacement cost of \$250 per square foot.

### Human Assets

Human assets include the entire statewide population. Several subsets of population are also evaluated in this Plan update including the elderly over the age of 65, children below the age of 18, and individuals below the federal poverty level.

Data for the analysis was provided by the Arizona Department of Health Services in the form census block level GIS data with 2015 population estimates. Table 3 summarizes the 2015 population's statistics by state and region that form the basis of the human asset database.

**Table 3: Population Statewide**

	Population			
Region	Total	Under 18	Over 65	Poverty Level
Central	4,604,414	1,216,158	618,612	748,257
North	772,157	177,450	158,170	163,483
South	1,458,367	354,191	242,700	268,372
<b>Totals:</b>	<b>6,834,939</b>	<b>1,747,800</b>	<b>1,019,482</b>	<b>1,180,112</b>

### State Loss Estimation

The estimation of potential losses is expressed in terms of population exposure and dollar losses due to damage to state-owned facilities and infrastructure. Wherever possible, a quantitative approach was used. The assessment for each hazard is typically based on a commonly accepted event type, such as the 100-year flood or a National Weather Service severe thunderstorm. The vulnerability assessment builds upon the hazard profile information by intersecting the state-owned assets and population estimates with the hazard profile data to generate a list of exposed assets. Exposure to loss ratios is then applied to estimate the potential amount of damage/loss that could be caused by each hazard event to state-owned critical facilities and infrastructure.

Some of the hazards profiled in this Plan will not include quantitative exposure and loss estimates. The vulnerability of people and state-owned facilities/infrastructure associated with some hazards are nearly impossible to evaluate given the uncertainty associated with where these hazards will occur. Instead, a qualitative review of vulnerability will be discussed to provide insight into the nature of losses that are associated with the hazard.

The following are summaries of the data included and updated in the vulnerability analysis section of each hazard profile, as appropriate. A description is provided for each table that details the update process and the steps taken to develop the data.

#### State-Owned Asset Loss Estimates by Region

Exposure and loss estimations for state-owned structures and facilities located within geospatially definable risk zones for hazards, such as flooding, wildfire, earthquake, fissure, subsidence and dam/levee inundation zones, are estimated using GIS tools and



methods. For other hazards with non-definable or uncertain risk extents, it is assumed that all state-owned facilities are equally exposed unless otherwise noted.

Where appropriate, loss estimates for state-owned structures and facilities are estimated by applying a loss ratio to the replacement values. Loss ratios, when used, are described and summarized within the hazard section. Losses are then aggregated by region. Where estimations of losses are not appropriate, aggregated exposure values will be reported.

### Population Sector Exposure Estimates

Estimates of human populations exposed to the Plan hazards identified within geospatially definable risk zones, are estimated using GIS tools and methods. For other hazards with non-definable or uncertain risk extents, it is assumed that all population sectors are equally exposed unless otherwise

### Local Vulnerability Summary

All of Arizona's 15 counties have developed risk assessments as a part of their local hazard mitigation plans that address their specific geographic areas. The results of these local risk assessments are summarized, and where appropriate, incorporated into the state level vulnerability analysis. When the local plan data is not readily available or the county did not assess a particular hazard, then a "No Data Available" note is applied. This summary considers one or more of the following elements in the local county plans:

- Probability of the hazard occurring in the jurisdiction
- Potential magnitude and severity of the hazard in the area
- Size of the population at risk in the jurisdiction
- Growth and development trends for the jurisdictions, especially in areas that may be affected by the hazard
- Existence and location of large populations with special needs such as the elderly, young, those meeting the federal poverty level, and non-English speaking communities
- Critical facilities and infrastructure that are vulnerable to the hazard

## HAZARD PROFILES

The hazard profile section was thoroughly reviewed and updated by the Planning Team as a whole and in specific by Planning Team members according to their area of expertise. The Planning Team contributed updated information to be used for the hazard mapping and profiling. The hazard profiles address the following:

- Description generally describes the hazard characteristics on a statewide basis.
- **History** - Information about previous significant hazard and occurrences in Arizona.
- **Probability/Extent** - A description and classification of the hazard probability based on historic records and/or statistical analysis of past events. The strength and magnitude of the hazard classifications is also discussed.

- **Warning Time** - How much notice is there before an event.
- **Future Conditions** - This section will discuss how conditions may change in the future in relation to climate change and the built environment. It will discuss the effects these future conditions may have on the frequency of occurrence and severity of the hazard risk.
- **Profile Maps** - Map(s) to illustrate the historic probability and extent posed by the hazard. The following information is characterized on a map for each region:
  - Number of presidential and/or gubernatorial disaster declarations
  - Recorded losses based on declaration data
  - Historically most damaging event for that region
  - Rate of Occurrence/Probability - Data on the rate of occurrence each year is based on an average of listed declared events from DEMA dating back to 1966.
- **Vulnerability Assessment** - A brief description of the results of the vulnerability analysis for each hazard summarized and mapped by state response region (North, Central, South). The vulnerability assessment, loss estimations and loss to exposure ratios are mapped, discussed and summarized by region, where appropriate. Each section discusses the following points:
  - **State-Owned Facilities Exposure and Loss Estimates**
  - **Vulnerable Population Groups** – A discussion and a map of each region showing the impacts of the hazard in relation to the following population groups: Limited English Proficiency, residents over 65 years of age, residents under 18 years of age, and those meeting the federal income poverty level.
  - **Local Jurisdiction Vulnerability** – A summary of the local plan vulnerability assessments for the counties within each region.
  - **Vulnerability Maps:** Graphical presentations by region of the vulnerable assets. Information on the map includes:
    - Number of State-Owned Critical Facilities Exposed and Estimated Losses
    - Population sectors exposed
    - Local jurisdiction critical facility exposure and/or loss estimates
  - **Specific Areas of Concern** – Discusses the highest vulnerability regarding specific communities and regions.
- **Potential Consequences and Impacts:**
  - Public
  - Property/Facilities/Infrastructure
  - Responders
  - Continuity of Operations/Delivery of Services
  - Environment/Cultural
  - Economic/Financial Condition of Jurisdiction

- Public Confidence in Jurisdiction's Governance
- Cascading/Secondary Impacts
- **Resources** - Provides resources available for information on the hazard per the following sub-categories:
  - **Sources** – A listing of sources for further investigation and understanding regarding the hazard.
  - **References** – A bibliography of literature, website, agency, and other published data sources used to develop the hazard profile.

## DAM FAILURE

Dams are structures that impound water above the natural prevailing grade using artificial structures such as earthen and/or rock embankments, concrete walls/structures, cement stabilized aggregate (CSA) or roller compacted concrete (RCC) embankments. Dams are normally constructed across or perpendicular to a watercourse (or watercourses) and will impound the intercepted water in a relatively static pool. The majority of dams in Arizona provide flood control, with many of the dams also serving as storage for irrigation and municipal water supplies. Several of the larger dams also provide hydro-electric generating capacity.

A dam failure results in an uncontrolled release of water to downstream areas, with potentially catastrophic impacts. Failures may be attributed to a variety of modes and causes. The three most common are foundation leakage and piping, overtopping, and spillway erosion. According to the National Research Council (NRC, 1983) these three modes have been responsible for 74% of the nation's historic dam failures.

Arizona's Dam Safety Program has existed since 1929. Funding for the program was minimal and sporadic until legislative approval of a consistent budget began in 1971, authorizing permanent staffing and the development of a comprehensive statewide Dam Safety Program.

The Arizona Revised Statutes (A.R.S.) §45-1201 assigns the responsibility for supervision of the safety of non-federal dams to the Director of the Arizona Department of Water Resources (ADWR). The mission of the ADWR Dam Safety Section is to maximize the protection of the public against loss of life and property by reducing the likelihood of catastrophic failure of dams within the state's jurisdiction. State statute defines a jurisdictional dam as an artificial barrier for the impounding or diversion of water either 25 feet or more in height or having a storage capacity of more than 50 acre-feet, with the following exceptions:

- Any barrier for the purpose of storing liquid-borne material (e.g., mine tailings dams),
- Any barrier that is a "release-contained barrier,"
- Any barrier that is federally owned and operated,
- Sole use transportation structures,
- Any barrier that is:
  - Less than six feet in height, regardless of storage capacity, or



Lynx Lake Dam and emergency spillway showing recent dam safety mitigation measures to raise the dam crest. Source: JE Fuller, 2009

- Between six and 25 feet in height with a storage capacity of less than 50 acre-feet, or
- Greater than 25 feet in height with 15 acre-feet or less of storage capacity.
- For an artificial barrier and/or appurtenant works structure to be considered a "release-contained barrier," following criteria should comply:
  - Has storage capacity that in the event of failure would be contained within the property that the release-contained barrier owner owns controls, operates, maintains or manages.
  - The property on which the release would be contained is not open to the public.
  - Owner will maintain downstream containment structures or sites with sufficient containment throughout the useful life of the release-contained barrier.

## HISTORY

The occurrence of dam failures has been limited in Arizona. Since 1966, there have been only three state declarations that directly pertained to dam related issues and no federal declarations. The following represent Arizona's historic dam failures or significant failure-threatening events that received a state declaration:

- April 19, 2004 - A state declaration was made for River Reservoir No. 3 Dam in Apache County (one of the Greer Lakes) due to concerns over observed seepage and internal erosion. Increases in seepage flow and eroded embankment soils reached a magnitude that appeared to indicate an imminent failure was possible. The County Sheriff mobilized personnel to monitor the dam on a 24-hour basis to provide early warning of a dam failure and to facilitate the evacuation of residents in the threatened downstream communities. No failure occurred, and over the next year the reservoir was drained and the dam was repaired.
- September 1997 - Centennial Narrows Dam in Maricopa County failed due to flooding from Hurricane Nora. This failure is significant because the single-purpose flood control dam most likely failed due to piping flow through transverse cracks in the dam. There were no significant damages downstream. The dam remains breached and is no longer in service (FCDMC, 1997).
- September 1978 - A state declaration was made for responding to the potential failure of the Tsaile Dam on Navajo Nation upstream of Chinle, AZ and Canyon del Muerto in the Canyon de Chelly National Monument. Seepage from the dam was forming sink-holes on the downstream face. The dam was drained, and interim repairs were made in 1982 and 1983 (USBR, 2011). Full dam safety repairs and modifications were performed by the Navajo Nation and US Bureau of Indian Affairs with construction completed in late 2015.



Narrows Dam – approximately 14-hours after breach failure.  
Source: Flood Control District of Maricopa County, 1997

- February 22, 1890 - The most significant dam failure experienced in the state occurred in Walnut Grove. The dam failed due to overtopping, and the ensuing flood caused an estimated 150 deaths and extensive destruction of property. The failure was blamed on the inadequate capacity of the spillway and poor construction (DEMA, March 1998). Located 30 river-miles north of Wickenburg on the Hassayampa River, the rockfill structure was 110 feet high, 400 feet long, had a base width of 140 feet, a top width of 10 feet, and a spillway of 5-20 feet long. The lake was 2.5 miles long by one-mile wide covering over 1,100 acres with an average water depth of 60 feet. The day before the breach, rain and snowmelt caused water in the lake to rise rapidly at a rate of about 1.5-feet per hour. A sheet of water three feet thick reportedly poured over the dam top for six hours. Between 1–2 am on February 22, 1890, the dam broke and the lake drained in less than two hours. The 80-foot wave front rushed down Box Canyon and reached Wickenburg, 30 miles downstream, in two hours. The flood-wave at Wickenburg was reported to be 40-foot high.

## PROBABILITY/EXTENT

The probability of dam failure in Arizona is low. However, it is recognized that a single failure event can result in catastrophic losses depending on the location, size, and storage capacity of the dam, and the downstream population and infrastructure. The state classifies hazard potential for each state regulated dam using downstream hazard and dam safety ratings. Table 4 and Table 5 summarize the hazard classes and dam safety ratings used for Arizona regulated dams. Federally owned dams not regulated by the state use similar hazard classes and are all high hazard dams.

**Table 4: Downstream Hazard Classes for State Regulated Dams**

Hazard Potential Classification	Loss of Human Life	Economic, Environmental, Lifeline Losses	EAP Required
Very Low	Not Likely	Limited to Owner or 100-year floodplain	No
Low	Not Likely	Low and generally limited to owner	No
Significant	Not Likely	Yes	Yes
High	Likely	Yes (not necessary for this classification)	Yes
Note: The hazard potential classification is an assessment of the consequences of failure, but not an evaluation of the probability of failure. Sources: ADWR and USACE (NID)			

The magnitude and extent of a dam failure is estimated by analyzing and mapping the flood inundation limits resulting from a projected failure event. State regulated significant or high hazard dams are required to develop an Emergency Action Plan (EAP). Significant and high hazard federal dams within Arizona typically have EAPs with failure inundation limits.

Map 2 shows the state jurisdictional and federal dam locations, with each attributed by hazard classification and safety rating (if regulated). This map does not include the dams owned by the City of Phoenix Water Services Department. The City requested the locations be confidential due to homeland security issues. Dam failure inundation limits and state-owned facilities/structures are also shown on the map. It is noted that the inundation limit database is a work in progress.



**Table 5: State Regulated Dam Safety Ratings**

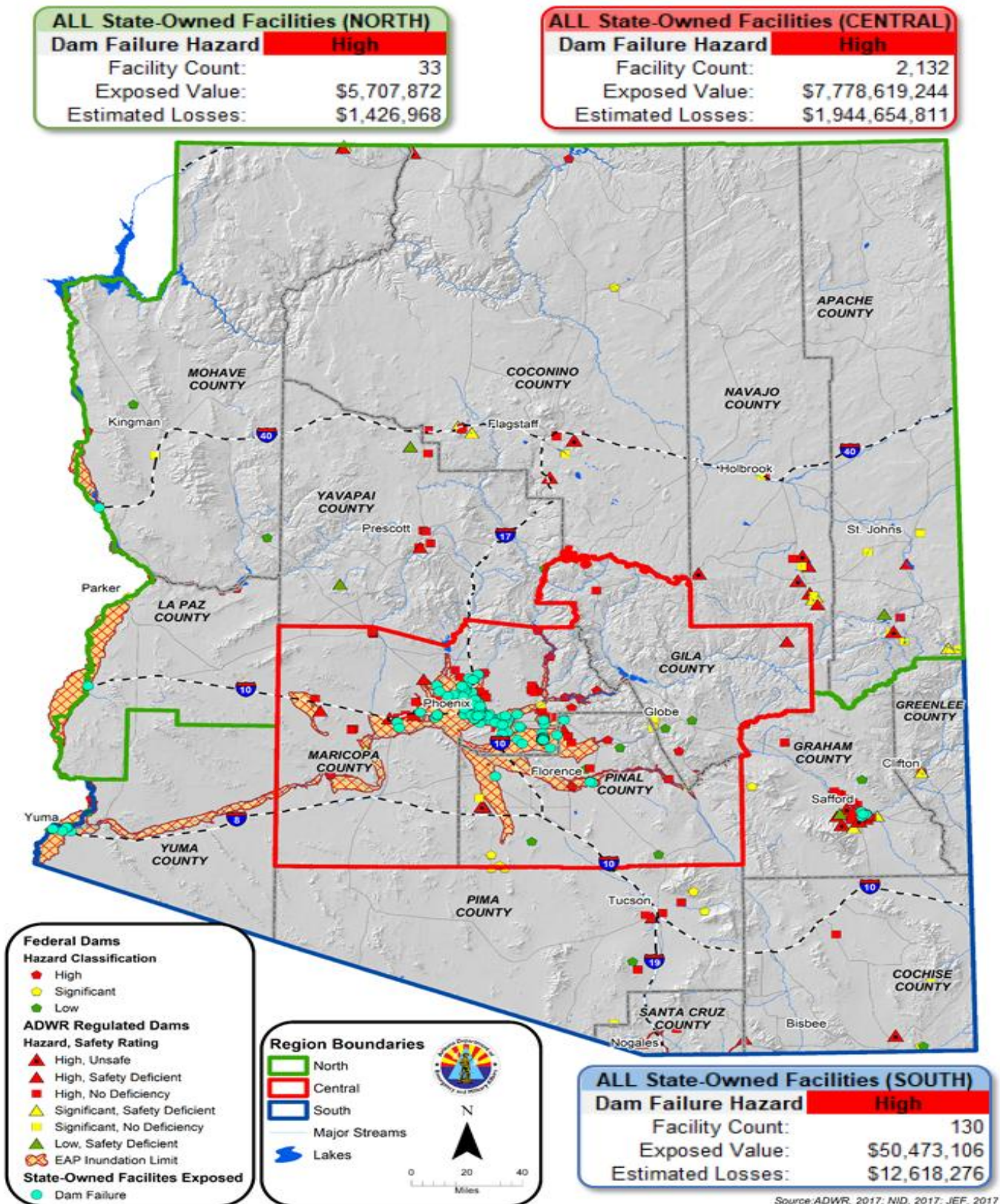
Safety Rating	Definition
No Deficiency	No safety deficiency determined.
Safety Deficiency	One or more conditions exist at the dam that impair or adversely affect the safe operation of the dam.
<b>Unsafe Categories</b>	
Category 1: Unsafe Dams with Elevated Risk of Failure	These dams have confirmed safety deficiencies for which there is concern they could fail during a 100-year or smaller flood event. There is an urgent need to repair or remove these dams.
Category 2: Unsafe Dams Requiring Rehabilitation or Removal	These dams have confirmed safety deficiencies and require either repair or removal.
Category 3: Unsafe Dams with Uncertain Stability during Extreme Events (Requiring Study)	Non-earthen dams that have been reclassified as high hazard potential and lack the necessary documentation demonstrating that it meets or exceeds standard stability criteria for high hazard dams during extreme overtopping and seismic events. The dam is classified as unsafe pending the results of required studies. Upon completion of these studies, the dams are either removed from the list of unsafe dams or moved to Category 2 and prioritized for repair or removal.
Category 4: Unsafe Dams Pending Evaluation of Flood-Passing Capacity (Requiring Study)	Dams that should be evaluated using updated methods to confirm their safety status. Upon completion of these evaluations, they are either removed from the list of unsafe dams or moved to Category 2 and prioritized for repair or removal.

## WARNING TIME

Once initiated, a dam failure can occur very rapidly, with a sudden, uncontrolled release of the stored or impounded water. Warning times for downstream populations is dependent upon the speed of the flood-wave and distance from the breach, usually measured in hours. Indicators of a potential problem or failure can manifest days, months or even years before an actual failure. Extreme weather events with a potential to trigger or cause a failure, will also have at least hours of warning if not a few days.



**Map 2: Dam Failure Hazard Statewide**



## **FUTURE CONDITIONS**

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### **Climate Considerations**

From a dam safety perspective, the primary climate change impacts will be related to potential changes in the way precipitation and resultant flood patterns may vary, and influence of the potential for increased wildfire activity. The National Climate Assessment (NCA) report (Garfin, et.al. 2014) notes that one of the anticipated impacts of climate change for the Southwest is a reduction in average annual precipitation and streamflow volumes. The report and supporting documents also indicate that winter storm intensities are anticipated to increase, which may lead to increased event-based flooding. The NCA report also notes that winter precipitation will be less in the form of snow and more frequently rain, which may indicate more frequent winter flooding. The overall flooding conditions for watersheds upstream of dam facilities could also be exacerbated by the potential for reduced vegetation due to increases in drought and post-wildfire flooding conditions.

### **Changes in Development**

The two, primary development related impacts to dam failure are:

- A phenomenon referred to as “development creep.” Development creep happens when development begins to encroach into the areas either protected by, or downstream of, dams. This encroachment can change the dam’s hazard rating and safety requirement due to increases in the number of people and structures situated within a failure inundation area. The encroachments can also increase the exposure of population and infrastructure to the risk of post failure inundation.
- Potential changes in watershed rainfall-runoff characteristics due to the addition of significant impervious areas can translate into increased runoff volumes that may exceed or challenge the design capacities of the dam structures.

### **North Region**

Apache, La Paz, and Navajo Counties have experienced little to no growth of any significance over the past five years, nor is there any major growth or development in dam failure areas anticipated over the next five years. Moderate growth has occurred in Coconino, Mohave, and Yavapai Counties and the trends of the past five years are anticipated to continue over the next five years with most of the growth being concentrated around existing population centers. Areas of anticipated significant growth that may extend into dam failure areas are identified in the Flagstaff (Coconino), Prescott Valley and Chino Valley (Yavapai), Bullhead City and Lake Havasu City (Mohave), plus several populated areas within the unincorporated sections of Coconino, Mohave and Yavapai Counties. None of the anticipated development is expected to alter any of the current dam hazard and safety ratings.

### **Central Region**

Significant growth has occurred in Maricopa and Pinal Counties over the past five years, and primarily in the build-out of previously planned residential, industrial and commercial areas. Growth in Gila County has been mostly limited to the Payson area. The federal and local dams impacting Maricopa County have been actively studied and

evaluated for failure inundation limits, with a large portion of the county being situated within an identified dam failure inundation zone. Development over the next five years will at least partially occur within these mapped areas. However, the risk of failure for most of the dams impacting the area is low due to the high level of maintenance and mitigation of potential failures. Planned growth in Pinal County areas subject to dam failure inundation is low to moderate and anticipated in or near Apache Junction, Coolidge, Florence, Maricopa, and portions of the San Tan Valley.

### **South Region**

Pima and Yuma Counties have experienced moderate growth over the past five years in some locations and population declines in others. Cochise County experienced moderate growth within Douglas and Sierra Vista, but generally a decline in the overall population. Graham County saw limited growth in the Pima-Safford-Thatcher area that is mostly attributable to the new Freeport McMoRan mining operations. Santa Cruz and Greenlee Counties have experienced limited to no significant growth. Moderate growth is expected to continue in Pima and Yuma Counties, primarily near or within the Tucson and Yuma Metropolitan areas, expanding the exposure to existing dam failure inundation zones. Future growth into dam failure zones within Cochise, Graham, Greenlee, and Santa Cruz Counties is not anticipated to be significant.

## **VULNERABILITY ASSESSMENT**

The estimation of potential exposure to the identified dam failure inundation hazards was accomplished by using GIS mapping and analysis tools to intersect the vulnerable population and state-owned critical facilities and infrastructure (CFI) data with the inundation limits depicted on the maps above, which are considered the high hazard areas for this analysis. The loss calculations assume that exposed structures are subject to a loss-to-exposure ratio of 0.25 (or 25% damaged). The exposure loss estimates presented are based on a single event and aggregated to the entire region.

Eight of the 15 county multi-jurisdictional hazard mitigation plans included dam failure in their risk assessment. Further details are summarized by region in the sections below.

### **North Region**

The North Region is the second-most vulnerable state region when considering the history of events, the exposure estimates and number of local plans that included dam failure in their risk assessment.

#### **State-Owned CFI Exposure and Loss Estimates**

A total of 17 state-owned CFI, or 1.6% of the statewide exposure, is located within dam failure inundation zones. The facilities exposed to dam failure inundation represent a total exposed replacement value of \$2.1 million, with an estimated \$500,000 in potential losses.

Additional state-owned facilities vulnerable to dam failure inundation hazards are the Arizona Department of Transportation (ADOT) operated and maintained freeways, highways and state routes located within the inundation zones. The drainage facilities



(bridges, culverts, and channels) constructed with the ADOT roadways are not expected to have capacity for handling the magnitude of flows associated with a dam failure.

### **Vulnerable Population Groups**

The 2015 estimated total population for the North Region is 772,157 people. Approximately 5.33% of the total population, or 41,166 persons, are exposed to dam failure inundation hazards. Exposure estimates for at-risk population groups like persons under 18-years of age, over 65-years of age, and those living at or below poverty level.

On average, approximately 7.3% of the North Region population is estimated to have a Limited English Proficiency (LEP) (US Census Bureau, 2016). Assuming the percentage is equally applied across the whole region's population, roughly 3,019 LEP persons (7.3% of 41,166) are estimated to be exposed to dam failure inundation.

### **Local Jurisdiction Vulnerability**

Local hazard mitigation plans for the North Region identified a total of 163 assets with a total replacement value of \$1.81 billion as exposed to dam failure inundation. Total potential losses to local CFI for dam failure inundation were estimated at \$398.3 million.

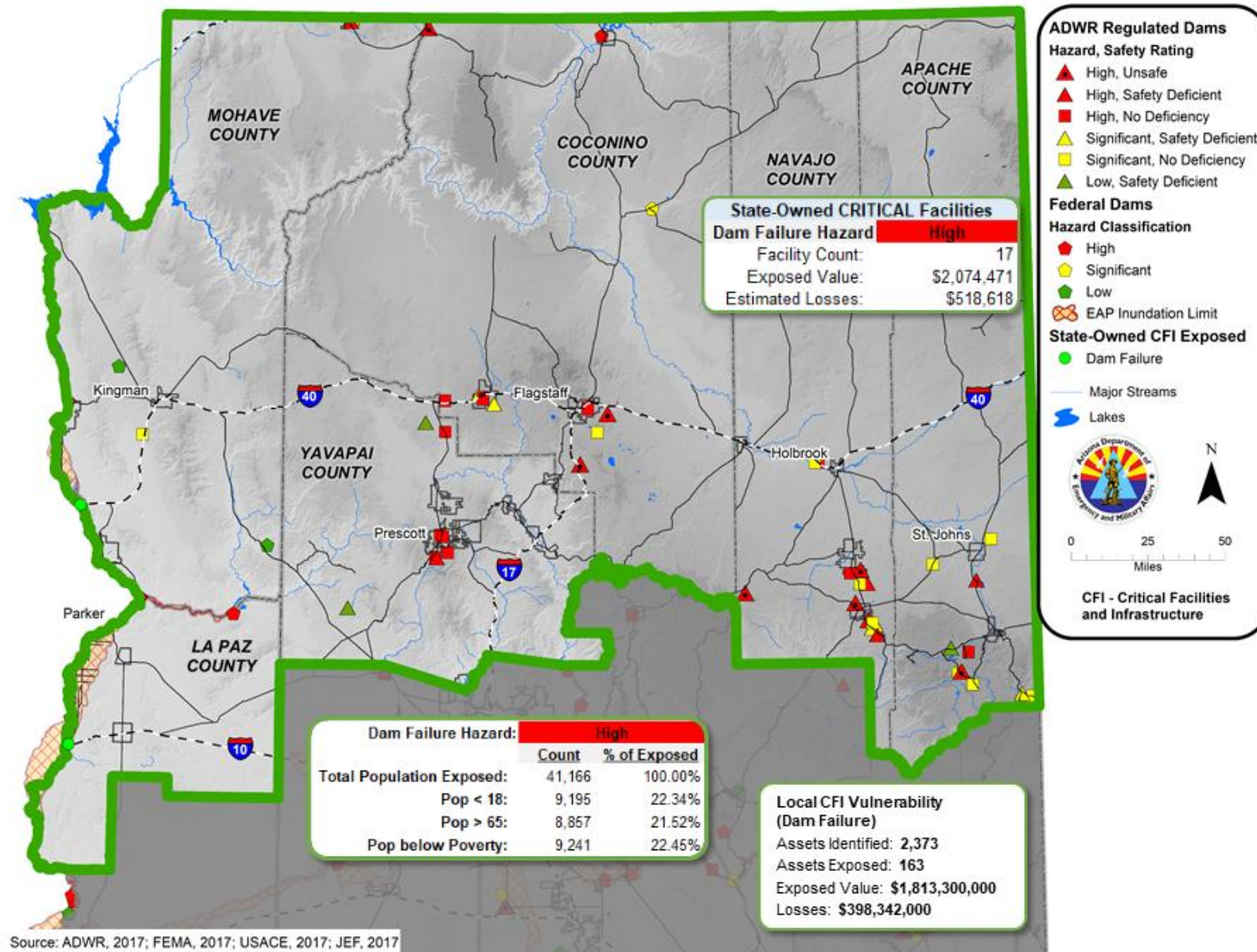
### **Specific Areas of Concern**

There are a number of high hazard dams in the North Region that have been identified as unsafe and either have outdated EAPs or require dam failure inundations limits to be digitized and added to the current database. These dams are located upstream of or near communities like Show Low, Taylor, Snowflake, Greer, Heber, and Munds Park. CFI and human exposure to the inundation limits from these dams are not accounted for in the numbers presented herein.

One area of concern regarding several dams located near or within North Region communities, is the possibility for post-wildfire flooding that could significantly overwhelm existing capacities. For example, Coconino County is conducting advanced post wildfire planning and risk assessments for the City of Williams, which has two municipal water supply reservoirs that are at risk of being overwhelmed with debris flow and flooding in a post-wildfire scenario.

## **Central Region**

Among the three state regions, the Central Region has the most significant vulnerability when considering the history of events, the exposure estimates and number of local plans that included dam failure in their risk assessment. Alternately, the Central Region arguably has the greatest amount of resources for active dam maintenance and repair, as well as modeling and mapping of hazard areas.

**Map 3: Dam Failure Vulnerability for North Region**

### State-Owned CFI Exposure and Loss Estimates

A total of 1,011 state-owned CFI, or 94.3% of the statewide exposure, are located within dam failure inundation zones. The facilities exposed to dam failure inundation represent a total exposed replacement value of \$2.1 billion, with an estimated \$532.8 million in potential losses.

State-owned and maintained roadways and infrastructure within the metropolitan Phoenix area are designed to meet local drainage requirements, and therefore are protected to 1% annual flood level. Although better than their rural counterparts, the numerous drainage facilities (bridges, culverts, and channels) constructed with the ADOT roadways are still not expected to have capacity for handling the magnitude of flows associated with a dam failure.

### Vulnerable Population Groups

The 2015 estimated total population for the Central Region is 4,604,414 people. Approximately 57.82% of the total population, or 2,662,502 persons, are exposed to dam failure inundation hazards. Exposure estimates for at-risk population groups like persons under 18-years of age, over 65-years of age, and those living at or below poverty level.

On average, approximately 6.7% of the Central Region population is estimated to have a Limited English Proficiency (LEP) (US Census Bureau, 2016). Assuming the percentage is equally applied across the whole region's population, roughly 177,500 LEP persons (6.7% of 2,662,502) are estimated to be exposed to dam failure inundation.

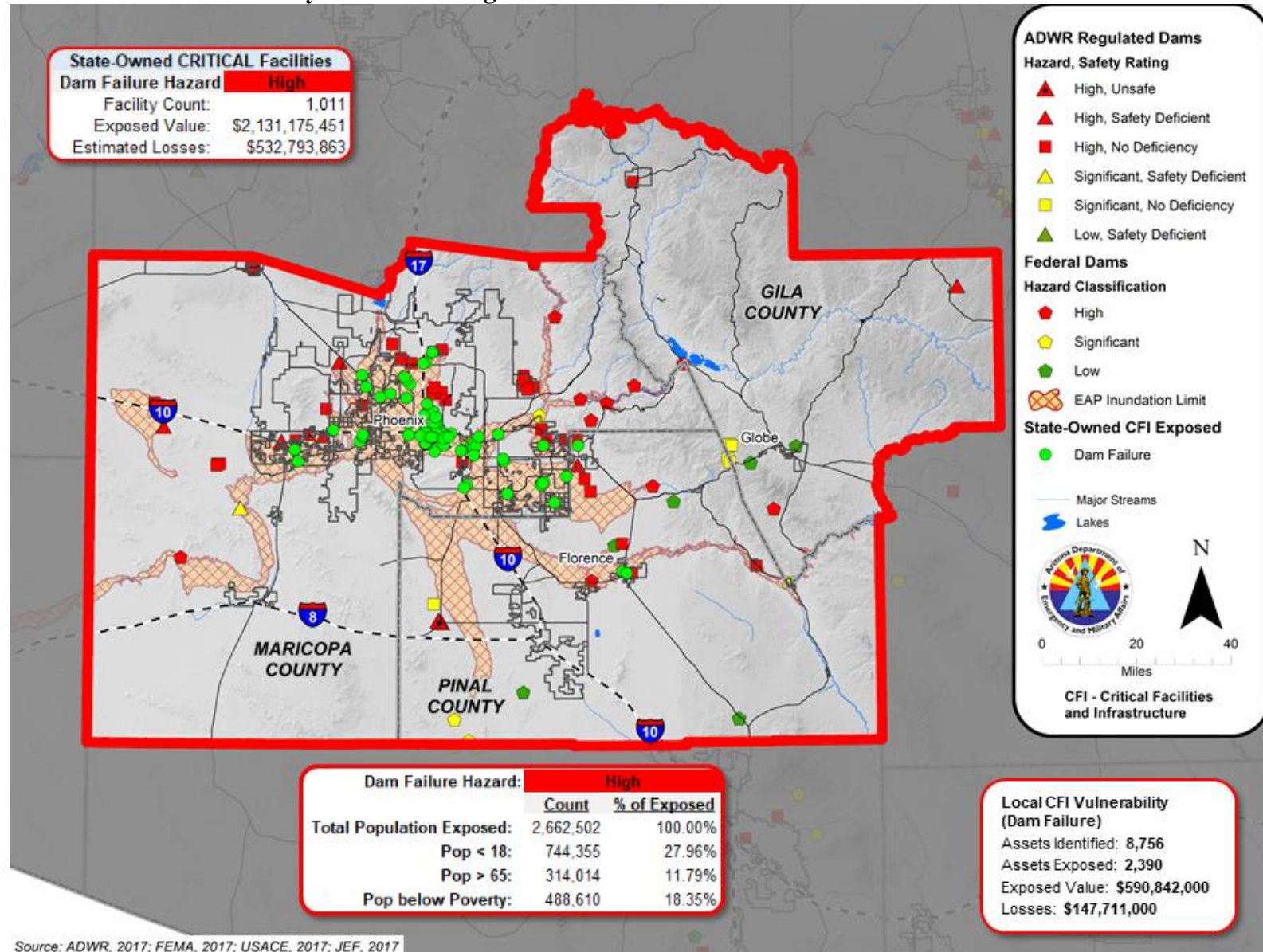
### Local Jurisdiction Vulnerability

Local hazard mitigation plans for the Central Region identified a total of 2,390 with a total replacement value of \$590.8 million as exposed to dam failure inundation. Total potential losses to local CFI for dam failure inundation were estimated at \$147.7 million.

### Specific Areas of Concern

There are two small flood retarding dams located in southwest Pinal County that are identified as unsafe and do not have mapped failure inundation limits reflected in the current database or this Plan. Both are relatively remote, but there are a small number of people located downstream, as well as a primary local highway.



**Map 4: Dam Failure Vulnerability for Central Region**



## South Region

The South Region is the least vulnerable state region when considering the history of events, the exposure estimates and number of local plans that included dam failure in their risk assessment.

### State-Owned CFI Exposure and Loss Estimates

A total of 44 state-owned CFI, or 4.1% of the statewide exposure, are located within dam failure inundation zones. The facilities exposed to dam failure inundation represent a total exposed replacement value of \$18.0 million, with a respectively estimated \$4.51 million in potential losses.

Additional state-owned facilities vulnerable to dam failure inundation hazards are the Arizona Department of Transportation (ADOT) operated and maintained freeways, highways and state routes located within the inundation zones. The drainage facilities (bridges, culverts, and channels) constructed with the ADOT roadways are not expected to have capacity for handling the magnitude of flows associated with a dam failure.

### Vulnerable Population Groups

The 2015 estimated total population for the South Region is 1,458,367 people. Approximately 7.86% of the total population, or 114,677 persons, are exposed to dam failure inundation hazards. Exposure estimates for at-risk population groups like persons under 18-years of age, over 65-years of age, and those living at or below poverty level.

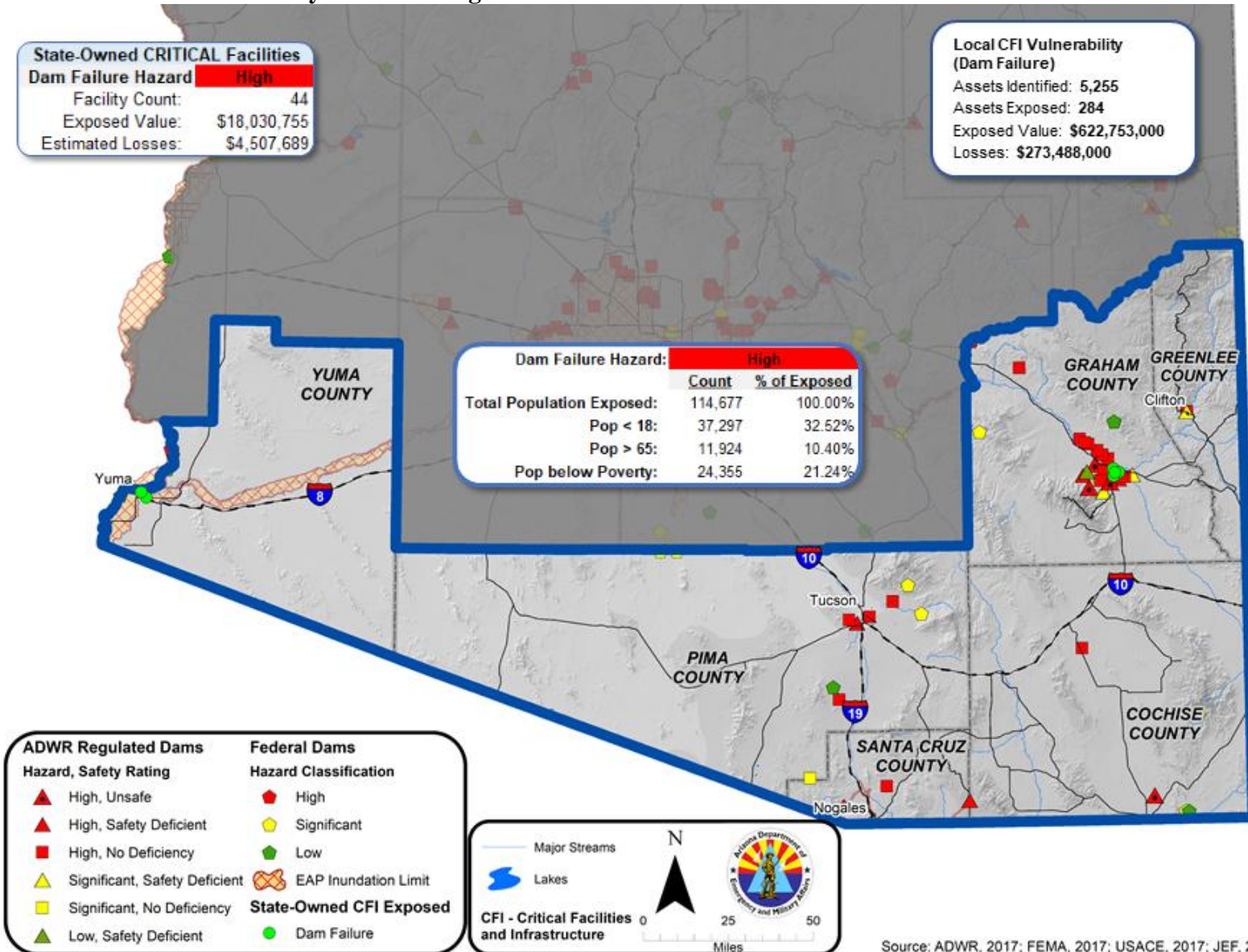
On average, approximately 12.7% of the Central Region population is estimated to have a Limited English Proficiency (LEP) (US Census Bureau, 2016). In Santa Cruz and Yuma counties, this number averages 23.5%. Assuming the percentage is equally applied across the whole region's population, roughly 14,526 LEP persons (12.7% of 114,677) are estimated to be exposed to dam failure inundation.

### Local Jurisdiction Vulnerability

Local hazard mitigation plans for the South Region identified a total of 284 assets with a total replacement value of \$622.8 million as exposed to dam failure inundation. Total potential losses to local CFI for dam failure inundation were estimated at \$273.5 million.

### Specific Areas of Concern

There are four dams located upstream of Safford and Thatcher that are currently designated by ADWR as unsafe. There have also been several wildfires in recent years that have burned portion of Mt. Graham, the base at which these dams are located. Failure of any one of these dams could be catastrophic for the downstream community and population.

**Map 5: Dam Failure Vulnerability for South Region**

## **POTENTIAL CONSEQUENCES AND IMPACTS**

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### **Public**

Flooding from dam failures can result in injuries and loss of life to the general public located within the inundation zone. Fatalities are usually due to drowning. Another very disruptive effect is when this hazard leads to isolation or evacuation. The evacuation alone can cause considerable trauma and stress for those affected, not to mention those who must find shelter for their pets and livestock. Long-term recovery will take months if not years, and in some cases permanent relocation may be required.

### **Property/Facilities/Infrastructure**

The flood-wave typically released by a dam failure can be very destructive both in force and flooding depths. Damage to most impacted, above ground property, structures and infrastructure is likely to be catastrophic, with the worst impacts being closest to the breach or failure location and dissipating in the downstream direction. Effects of large scale failures can impact areas miles downstream of the failure. The potential for significant erosion and scour also threatens buried infrastructure.

### **Responders to the Incident**

Much like the dangers of flooding, dam failure incident responders may experience injury due to debris, drowning, electrocution, cold stress and exposure to hazardous materials because flooded disaster sites are unstable, clean-up workers might also encounter sharp, jagged debris, biological hazards in the flood water, exposed electrical lines, blood or other body fluids, and animal and human feces and remains. Responders are prone to the same dangers as the general public, only on a higher level as they may be putting themselves in harm's way by performing rescue activities.

### **Continuity of Operations/Delivery of Services**

Maricopa County is home to the State Capitol and the primary state agency buildings, which are nearly all located within an identified dam failure inundation zone for a failure of the Salt River Project dams. In the event of such a dam failure, the agencies housed in these buildings may be significantly impacted and hindered in providing critical operations and services. It is noted that the probability for such an event is extremely low. Failures of other dams across the state may have an impact of some state operations, but not to a significant level.

### **Environment/Cultural**

The impacts to environmental and cultural resources are a magnified version of what might occur with regular flooding. As such, please refer to the Flooding Section for further discussion.

### **Economic/Financial Condition of Jurisdiction**

The impacts to the economic and financial condition of the state are a magnified version of what might occur with regular flooding. As such, please refer to the Flooding Section for further discussion.

## Public Confidence in Jurisdiction's Governance

Effects on the public's confidence in the state's governance are a magnified version of what might occur with regular flooding. Dams being evaluated and maintained by government agencies increases the probability that public confidence will decline after a dam failure event. Public perception may be focused on the fact that the incident may have been prevented if the dam was properly evaluated and maintained. Responsible agencies notifying the public of any issues and maintaining flood control measures are essential to ensuring public confidence. Please refer to the Flooding Section for further discussion.

## Cascading/Secondary Impacts

Cascading or secondary impacts are a magnified version of what might occur with regular flooding. As such, please refer to the Flooding Section for further discussion.

## RESOURCES

### Sources

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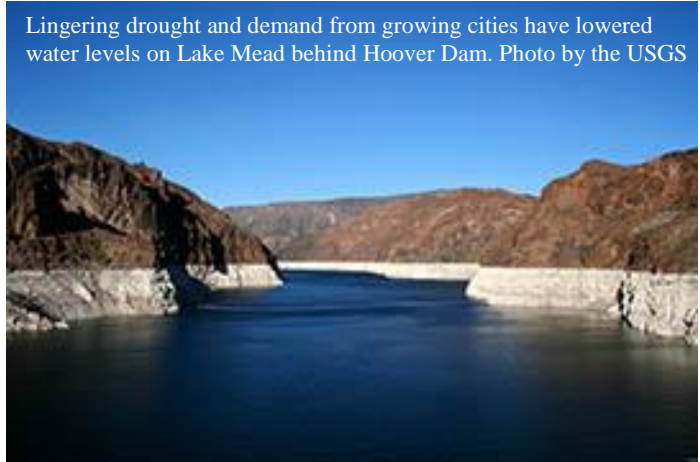
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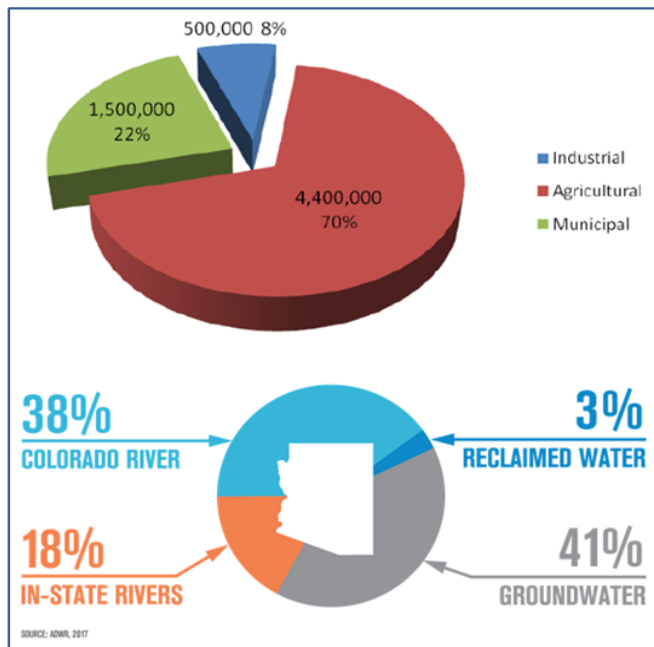


## DROUGHT

Drought is a weather-related phenomenon that can occur in virtually all climatic zones, and specifically in arid locations. Drought is a natural occurrence that has the potential to negatively affect humans, animals, and the environment. It is different from normal aridity, which is a permanent characteristic of the climate in areas of low rainfall, but Arizona's arid conditions and low precipitation patterns make it susceptible to drought of moderate durations and intensities. Drought originates from an extended deficiency of normal precipitation that usually spans one or more seasons in length, and can result in a water shortage for some activity, group, or environmental sector.



Arizona is also affected by drought conditions that extend beyond Arizona's borders and into the greater Colorado River watershed. Water from the Colorado River provides Arizona with a significant portion of its water supply, and the Colorado River watershed has experienced severe drought conditions since 2000. Colorado River water is stored in a system of federally constructed and regulated dams and reservoirs that harness its flows for use by several states before discharging to Mexico at the southwest corner of the state. Arizona, California, Nevada, New Mexico, Utah, Colorado, Wyoming, and Mexico share the river's resources, and rights to use Colorado River water are quantified by a string of legal authorities known as the "Law of the River." Based on this body of law, Arizona has the right to use 2.8 million acre-feet annually of Colorado River water.



Drought is a complex natural hazard and its impacts result from the interaction between the natural event (less precipitation than expected) and the demand people place on the water supply, which may include agricultural, municipal, industrial, and natural uses.

Drought differs from some of the other natural hazards in three ways. First, the onset and end of a drought are difficult to determine due to the slow manifestation and lingering effects of an event after its apparent end. Second, the lack of an exact and universally accepted definition adds to the confusion of its existence and severity. Third, drought is not an event or incident-based hazard, but more of a long term condition with subtle, less obvious changes in

conditions that develop over a period of years and may be spread over large geographical areas.

All economic activity within Arizona, including mining, irrigated agriculture, industry, tourism and urban and rural growth can occur only where dependable water supplies are available. As a result, Arizona places a high priority on managing its limited water to ensure that secure water supplies are available now and well into the future. According to ADWR<sup>1</sup> and illustrated in the graphic above, Arizona used 7.4 million acre-feet of water in the 2016 water year, which was divided amongst three major categories of users: municipal (22%), industrial (8%), and agricultural (70%). Sources for the water included the Colorado River (38%), groundwater (41%), in-state rivers (18%) and reclaimed water (3%).

Throughout the last half-century, groundwater has been extracted more rapidly than it can be replenished, leading to a condition known as overdraft. Continued overdraft of the state's finite groundwater supplies will challenge the state's ability to ensure a secure water supply for the future.

In-state surface water from lakes, rivers, and streams is a major renewable resource for the state. Several storage reservoirs and delivery systems have been constructed throughout the state to make the best use of the surface water when and where it is needed, with the most notable being the systems located on the Salt, Verde, Gila, and Agua Fria rivers. Almost all of the natural surface water in Arizona has been developed.

Reclaimed water, or effluent, is the one water source in the state with potential for increase. As the population and water use grows, more treated wastewater will be available for use. Reclaimed water is treated to a quality that can be used for purposes such as agriculture, golf courses, parks, industrial cooling, or maintenance of wildlife areas.

## HISTORY

As of October 2017, Arizona has experienced 22 droughts declared as drought disasters/emergencies by the Governor's Office and the Secretary of the US Department of Agriculture (USDA). For 2017, La Paz and Yuma Counties were designated as primary disaster areas, with Maricopa, Mohave, Pima, and Yavapai Counties being named as contiguous disaster counties.

Historically, the state has experienced several drought events. Average annual precipitation records dating from 1895 to present<sup>2</sup> (121 years of record) provide a snapshot of past drought periods when evaluated on the basis of how the average annual precipitation for any given year varies from the normal of the whole data set.

Between 1849 and 1905, the most prolonged period of drought conditions in 300 years occurred in Arizona (NOAA, July 29, 2003). Another prolonged drought occurred during the period 1941-1965, during which time there were no spill releases into the Salt River (DEMA, 2001). Another short dry period from 1968-1977 followed shortly after. The period from 1979-1983 appears to have been anomalously wet, while the rest of the historical records shows that dry conditions are most likely the normal condition for Arizona.

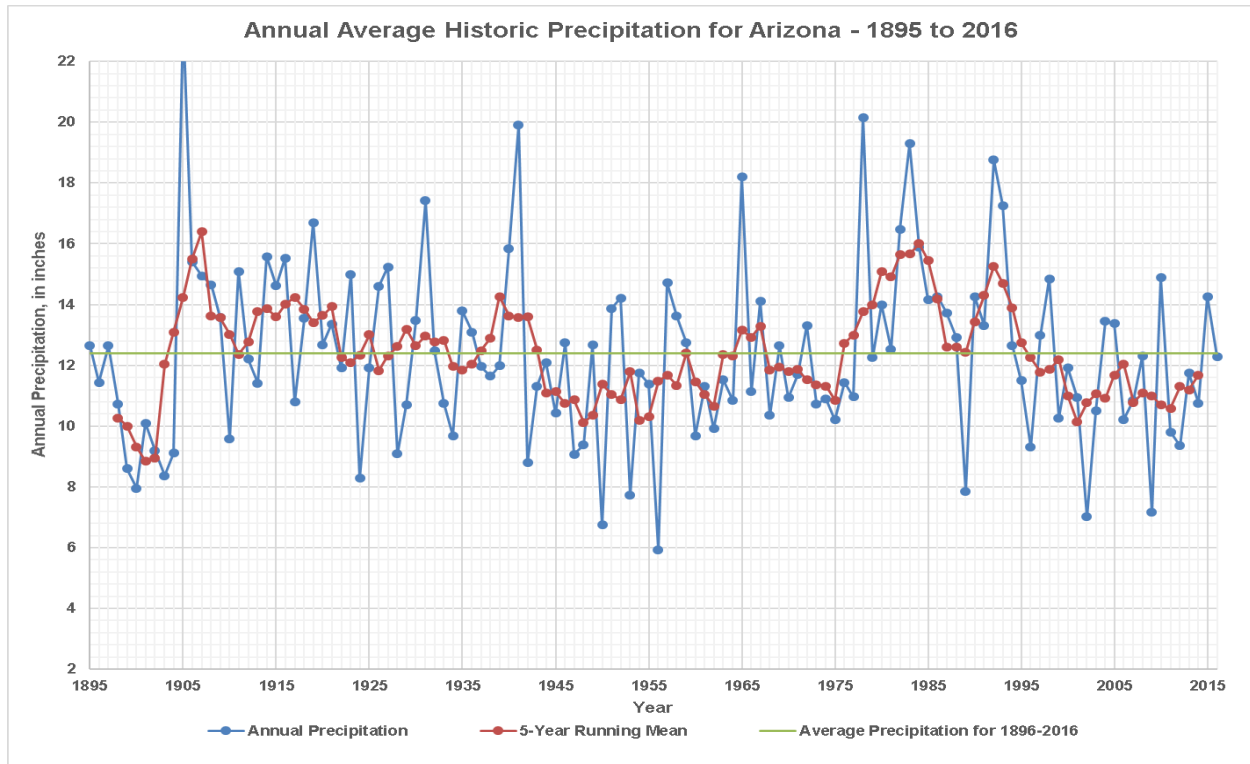
<sup>1</sup> ADWR, 2017, <http://www.azwater.gov/AzDWR/PublicInformationOfficer/documents/supplydemand.pdf>

<sup>2</sup> WestMap Climate Analysis & Mapping Toolbox, 2017, [https://cefa.dri.edu/Westmap/Westmap\\_home.php](https://cefa.dri.edu/Westmap/Westmap_home.php)



The current drought began in 1995 and has persisted until now. The four wetter than normal years within that period have brought some relief, but have not been enough to ameliorate the drought. A recent study of past droughts (A.D. 762-2005) in the southwest using tree ring data (Meko et al. 2007) found that droughts in the past have lasted as long as 60 years, with reduced streamflow lasting an average of 25 years. The data suggests that extended drought is a normal condition in the southwest, and the wet decades of the 1970s and 1980s are uncharacteristic.

**Figure 1: Annual Precipitation Averages Statewide**



## PROBABILITY/EXTENT

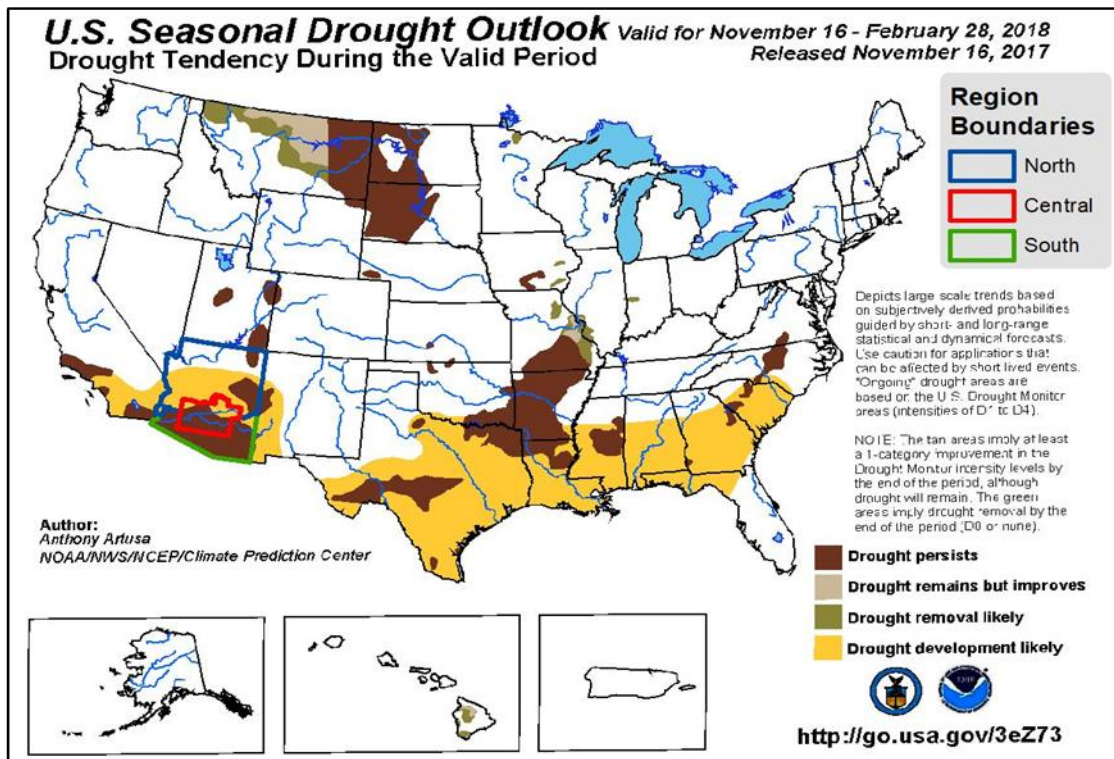
Given the past history, the probability of drought occurring (or in the case of current conditions, continuing) in any location within the state is high. A drought's severity depends on numerous factors, including duration, intensity, and geographic extent as well as regional water supply demands by humans, animals, and vegetation. Due to its multi-dimensional nature, drought is difficult to define in exact terms and also poses difficulties in terms of comprehensive risk assessments. This is due to the "snapshot in time" nature of drought severity and predictive tools. What is valid for today, will likely change in the next day, or week or month depending on the season, the amount of precipitation, or lack thereof, and user demand.

The magnitude of drought is usually measured in time and the severity of the hydrologic deficit. The changing climate and continued population growth may increase the probability, extent, and severity of future drought events.

## WARNING TIME

Warning time in relation to drought is generally not relevant, as the determination for the existence of a drought is developed from evaluation of the past months and years of temperature and precipitation data to the long-term record normal. Future potential for changes to a current drought cycle use meteorological modeling to develop predictions of near future temperature and precipitation levels, and then apply those data to assess future changes in drought severity. The US Seasonal Drought Outlook (USSDO) is one such product that is distributed by the National Weather Service's Climate Prediction Center<sup>1</sup>.

**Figure 2: Drought Seasonal Outlook**



## FUTURE CONDITIONS

### Climate Considerations

Future climatic conditions for temperature and precipitation will directly impact the future duration and severity of drought cycles in Arizona. Publications and studies produced over the last 10-years generally agree on a potential warming trend over the past century that is anticipated to continue into the 21<sup>st</sup> century. The same research is inconclusive on the amount of precipitation change expected, except that all tend to agree that a potential for reduction in snowpack and streamflow amounts are projected for parts of the Southwest, resulting in

<sup>1</sup> National Weather Service, Climate Prediction Center, [http://www.cpc.ncep.noaa.gov/products/expert\\_assessment/sdo\\_summary.php](http://www.cpc.ncep.noaa.gov/products/expert_assessment/sdo_summary.php)

decreases of surface water supply reliability for cities, agriculture, and ecosystems (Garfin, et. al., 2014). Given the current research, it is anticipated that drought cycles will continue and may worsen in the future when compared to the recent past. Even without reduced snowpack and precipitation, the warmer temperatures enhance evaporation leading to drier soil and vegetation.

### Changes in Development

Increases in development that accompany the anticipated growth of Arizona's population and economy are all dependent upon reliable water sources. For each of the state regions, the water demands imposed by additional population and industry, and the ability to meet those demands, will be directly impacted by drought. Most of the growth anticipated over the next plan cycle is expected to concentrate around current population centers. Reduced yields from increasing temperatures and increasing competition for scarce water supplies may displace jobs in some rural communities<sup>1</sup>.

#### North Region

The majority of the anticipated growth in the North Region is expected to expand from existing cities and towns. New growth will rely on either groundwater, or in-state surface water sources. The primary agricultural demand is livestock related water sources for range animals, which are not expected to grow significantly due to range management constraints.

#### Central Region

The most significant development in the Central Region is expected to primarily occur in the Phoenix Metropolitan Area. Drought impacts are less constraining in the Central Region due to the multiple sources of water available to Maricopa and Pinal Counties. Gila County constraints are more similar to the North Region. The Southwest US produces more than half of the nation's high-value specialty crops, which are irrigation-dependent and particularly vulnerable to extremes of moisture, cold, and heat. A significant portion of that agriculture is located within the Central Region. In some areas, conversion of agriculture areas into residential and retail commercial development may change the water demand profile.

#### South Region

The most significant development in the South Region is expected to primarily occur in the Tucson Metropolitan Area. Drought is already causing development constraints where new development depends on access to a diminishing or highly regulated groundwater supply. Potential developments in Benson (Cochise County) have faced challenges in obtaining development rights, as the use of water might impact the health of the San Pedro River<sup>2</sup>. A significant portion of the high-value specialty crops previously

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<sup>1</sup> Garfin, G., G. Franco, H. Blanco, A. Comrie, P. Gonzalez, T. Piechota, R. Smyth, and R. Waskom, 2014, *Ch. 20: Southwest. Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., USGlobal Change Research Program, 462-486. doi:10.7930/J08G8HMN

<sup>2</sup> Kolsrud, E. (2017) *House Development Challenges Benson, San Pedro River*. Arizona Sonora News. <http://arizonasonoranews.com/house-development-challenges-benson-san-pedro-river/>

mentioned, are located in the Southern Region and especially in the Yuma Valley. In some areas, conversion of agriculture areas into residential and retail commercial development may change the water demand profile.

## VULNERABILITY ASSESSMENT

All population sectors are equally exposed to drought. The severity and magnitude of the drought conditions, however, fluctuate in time and geography depending on the season, the amount of precipitation or lack thereof, and user demand. No vulnerability maps are provided in this section. Instead, vulnerability is discussed on a more general basis for each region.

Drought generally is not a direct source of damage to state-owned facilities and no losses are estimated for this Plan. The state does, however, experience economic loss in other ways. For example, during significant drought conditions, the AZ Game and Fish Department will haul water for critically impacted wildlife, and perform special fishery management to compensate for reduced lake levels or streamflow. These efforts have a negative economic impact on the state.

### North Region

The North Region is considered to be second-most vulnerable due to the multiple in-state surface water sources, higher precipitation rates, and lower average temperatures. The portions of Mohave and La Paz Counties that are generally situated along the Colorado River (Bullhead City, Lake Havasu City, Parker, etc.) generally rely on Colorado River water as their principal water supply. The remaining areas are dependent on surface water and groundwater. Extended drought periods can impact forest health and wildfire susceptibility. Range animals (both livestock and wildlife) are vulnerable to extended droughts as forage and water sources dry up.

#### State-Owned CFI Exposure and Loss Estimates

All 1,988 state-owned facilities representing \$2.4 billion in replacement value are exposed to drought. No losses are estimated.

#### Vulnerable Population Groups

The entire 2015 estimated population of 772,157 people are considered to be equally exposed to drought. This includes all of the sub-population groups of under 18-years of age, older than 65, poverty level, and LEP.

#### Local Jurisdiction Vulnerability

None of the local jurisdictions in the North Region estimated losses for locally identified critical and non-critical facilities. All assumed that local facilities and populations were equally exposed. See the section titled “Local Agricultural Vulnerability” for further discussion on locally estimated losses in agricultural sectors.

#### Specific Areas of Concern

Drought related declines in snowpack depths in the northern mountain areas will result in decreased surface water flows during the latter part of the summer and early fall, forcing a greater reliance on groundwater and reservoir storage. Depths to groundwater for many areas in the North Region make installing and operating wells very expensive. Increased

reliance on these groundwater resources during times of severe drought, or lowering of groundwater tables due to increased pumping rates, could become a significant problem. Long duration droughts will also dry forested areas, increasing the wildfire risk.

The Fort Mojave Indian Reservation sits on the border of Arizona, California, and Nevada in the North Region. The reservation is experiencing extreme drought conditions that will impact their culture and traditional practices as it places greater stress on traditional fish, plant, and animal species. The Hualapai Tribe is also located in the North Region and also faces impacts from lack of water supply due to drought. The current water source for their population center of Grand Canyon West, is located 35 miles away and delivers only 45 gallons per minute.

## Central Region

The Central Region is considered to be the least vulnerable to drought due to the availability of multiple water sources (Colorado River, Salt River Project, and groundwater). The only exception to this ranking would be if a severe drought were to persist or develop in the Colorado River Watershed since Colorado River water comprises a significant portion of the water currently used in the Central Region. See the Specific Areas of Concern section for additional discussion.

### State-Owned CFI Exposure and Loss Estimates

All 3,464 state-owned facilities representing \$9 billion in replacement value are exposed to drought. No losses are estimated.

### Vulnerable Population Groups

The entire 2015 estimated population of 4,604,414 people are considered to be equally exposed to drought. This includes all of the sub-population groups of under 18-years of age, older than 65, poverty level, and LEP.

### Local Jurisdiction Vulnerability

None of the local jurisdictions in the Central Region estimated losses for locally identified critical and non-critical facilities. All assumed that local facilities and populations were equally exposed. See the section titled “Local Agricultural Vulnerability” for further discussion on locally estimated losses in agricultural sectors.

### Specific Areas of Concern

The Central Arizona Project (CAP) delivers approximately 1.5 million-acre feet of Colorado River water to Maricopa and Pinal (Central Region) and Pima (South Region) Counties. Reliance upon Colorado River water may result in a significant water shortage should the current drought cycle persist or worsen. According to a report from the Interagency Coordinating Group (ICG, 2017), “... *conservation efforts and the wet winter helped keep Lake Mead out of a shortage in 2018; however, the probability of shortage in the very near future is still significant at 15% for 2019 and over 40% for the next three years. Furthermore, based on the last 28 years of historical hydrology, there is about 50% chance that Lake Mead will decline to a critically low elevation of 1,025 feet in as early as 2026.*” Lowering of Lake Mead to critical levels will trigger delivery reductions that follow a prescribed allocation that is based on a hierarchy of water rights. Much of



the water currently delivered to Central Region municipalities are junior water rights and will be the first to be reduced. Those reductions will trigger significant conservation and demand reduction measures for the state's largest population area.

## **South Region**

The South Region is considered to have the highest vulnerability to drought in the state. This is largely due to the heavy reliance upon dwindling groundwater and limited surface water resources. Agencies within Pima County also receive Colorado River water via the CAP, but proportionately less than users in the Central Region. The Wellton-Mohawk Water District is the primary distributor of Colorado River water to Yuma County agricultural users.

### **State-Owned CFI Exposure and Loss Estimates**

All 1,505 state-owned facilities representing \$5.2 billion in replacement value are exposed to drought. No losses are estimated.

### **Vulnerable Population Groups**

The entire 2015 estimated population of 1,458,367 people are considered to be equally exposed to drought. This includes all of the sub-population groups of under 18-years of age, older than 65, poverty level, and LEP.

### **Local Jurisdiction Vulnerability**

None of the local jurisdictions in the North Region estimated losses for locally identified critical and non-critical facilities. All assumed that local facilities and populations were equally exposed. See the section titled "Local Agricultural Vulnerability" for further discussion on locally estimated losses in agricultural sectors.

### **Specific Areas of Concern**

Potential Colorado River water reductions will impact the Tucson area in a manner similar to that of the Central Region. Persistence or worsening of the current drought will also force a significant increase in groundwater withdrawals that may translate into other hazards such as increased fissure and subsidence development, and the lowering of baseflow elevations in critical perennial streams and rivers. The South Region is particularly vulnerable to drought due to the heavy reliance on groundwater supplies. Cochise County, for example, relies almost exclusively on groundwater wells. Lack of surface water supplies has increased pumping, and past and present drought cycles have failed to recharge the aquifers. Severe subsidence, desiccation cracks, and earth fissures have developed in the area. Large cottonwoods and mesquite trees in the riparian area are dying near Willcox, Benson, and McNeal due to lack of precipitation and lowering of stream base-flow levels.

## **Local Agricultural Vulnerability –**

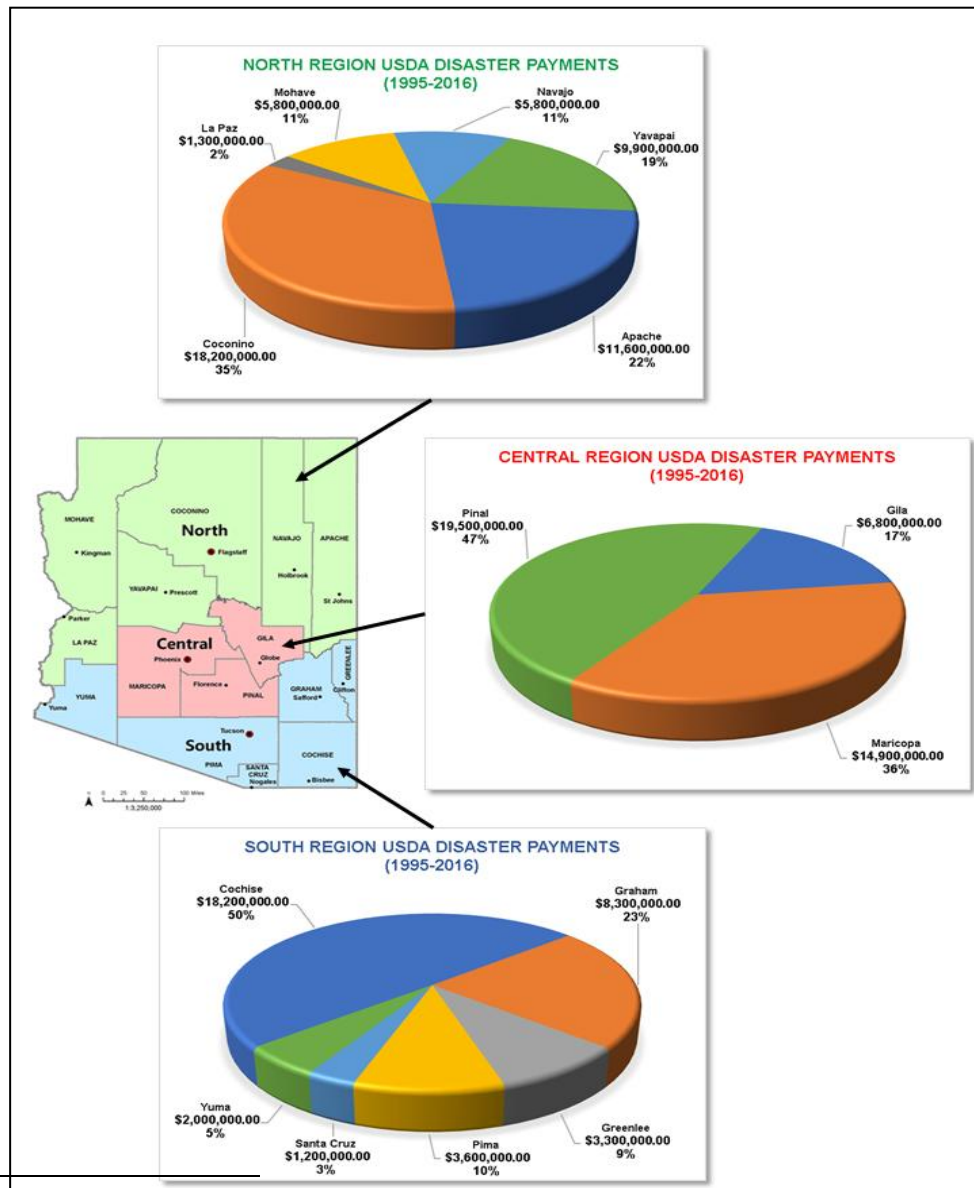
Thirteen of 15 local county hazard mitigation plans included drought as a top hazard, and expressed vulnerability as potential impact to certain sectors of the county's economy and natural resources including:

- Crop and livestock agriculture

- Municipal and industrial water supply
- Recreation/tourism
- Wildlife and wildlife habitat

One measure of vulnerability used in the county plans was the amount of USDA disaster payments received by local farmers and ranchers that related to drought. Using the same data source<sup>1</sup>, Figure 3 summarizes the reported drought-related disaster payments received by each county and summarized by region for the period of 1995 to 2016. On average, North Region farmers and ranchers (mostly ranchers) received the highest amount at \$2.50 million per year. The Central Region was next with \$1.96 million per year. The South Region was lowest with \$1.74 million per year.

**Figure 3: Drought-related USDA Disaster Payments**



<sup>1</sup> Environmental Working Group, 2017, data accessed at the following link: <https://farm.ewg.org/index.php>



## **POTENTIAL CONSEQUENCES AND IMPACTS**

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### **Public**

Direct impacts to public health and safety due to the effects of drought conditions are usually related to water supply issues. For example, the City of Williams faced a severe water shortage when surface water sources were dry and wells exceeding 2,500 feet in depth were rendered useless due to lowering of the aquifer. The effects of impacts like these that continue for long periods of time could be devastating to a community. Indirect impacts are also likely and are typically seen in the form of damage to the environment which could impact agriculture, food supply, and the economy. The economy could suffer if the environment were impacted to the point that it affected businesses that depend on support from the environment. These impacts are translated into the general economy in the form of higher food and agricultural goods prices.

### **Property/Facilities/Infrastructure**

Direct impacts of drought on the built environment are generally not measurable or significant for the normal drought cycles typical to the arid Southwest. Cultivated agricultural properties are at the greatest risk to long-term, severe droughts in the potential loss of topsoil to and conversion of fertile land into barren deserts typical of the 1930's dust bowls.

### **Responders**

Similar to the impact to the public, there should be no threat to responders as this is not considered an 'incident' response type of hazard. However, increased potential for severe dust storms, wildfires, heat-related illness, and other secondary impacts of drought, may strain resources and generate the need for additional personnel and equipment.

### **Continuity of Operations/Delivery of Services**

Drought is not a major threat to the state's ability to continue effectively functioning. Drought demands cutbacks at all levels, but this should not significantly hinder the continued operation of state agencies, services, and responsiveness. One area that may require additional effort and attention would be sourcing water for various operations requiring a ready water supply.

### **Environment/Cultural**

Extended drought may weaken and dry the grasses, shrubs, and trees of wildfire areas, making them more susceptible to wildfire. Drought also tends to reduce the vegetative cover in watersheds, which decreases the interception of rainfall and increases the flooding hazard. Subsidence conditions are aggravated when lean surface water supplies force the pumping of more groundwater to supply the demand without the benefit of recharging from normal rainfall. Cultural impacts of extended drought include stress on small, agricultural communities, and especially the Indian Tribes with significant reliance on the agricultural industry.

### **Economic/Financial Condition of Jurisdiction**

Drought can impact an area financially as it impacts water supply for the public, industry, agriculture, and recreational demands. Long-term drought jeopardizes water resources and hinders the development of new properties due to the lack of being able to secure a 100-year

assured water supply certificate. No growth translates directly into an economic loss for the community and potentially the loss of industry that is reliant upon a ready source of water. Agricultural impacts to both farming and ranching can create market shortages which can drive the prices up for the impacted commodities. Rangeland ranching is dependent on groundwater and captured rainfall runoff via stock tanks and rain catchments. Extended drought conditions reduce rangeland grasses and other fodder. Stock tank water levels and replenishment are also significantly reduced. This forces ranchers to feed more hay and to truck in water to sustain their rangeland herds. The expense of these activities forces ranchers to drastically reduce herd sizes, flooding the markets with excess animals and tumbling livestock prices. Then as supplies in following years are drastically reduced due to lack of rangeland and water, prices soar. Water utility costs are likely to increase as groundwater levels drop and the need for greater storage capacity increases. Loss of tourism and recreation-based revenue yielded by activities such as hunting, fishing, skiing, hiking, etc., and decreased recreational equipment sales/use could affect the operation of recreational facilities that depend on water.

### **Public Confidence in Jurisdiction's Governance**

Severe drought periods may impact the ability of water utilities and municipal agencies to deliver continuous water, which may diminish the public's confidence in the agency's ability.

### **Cascading/Secondary Impacts**

In the west, drought is a cumulative hazard, in that a single week, month, or year of below average precipitation does not define a drought. Since impacts of drought are also slow to develop, secondary and cascading effects may be felt several years after the drought begins. The primary impacts of drought include reduction of surface and groundwater resources for human and industrial consumption, hydroelectric power generation, recreational use and navigation, water quality decline through reduced dilution of contaminants, increased wildfire activity; and loss of livestock and wildlife (biodiversity) due to lack of forage and dry watering holes. The secondary effects include erosion of slopes and river channels due to loss of vegetation; loss of forests due to insect infestation in weakened trees (bark beetle for example); dust storms due to loss of vegetation; soil degradation and air pollution; and ground subsidence and fissure development due to over-pumping of groundwater. Socio-economic secondary effects include increased public health risk, increased food prices, and increased conflict between water users. Drought can also increase the costs of digging wells and pumping groundwater as drought can lower the historic groundwater levels. The need to develop additional water supplies and invest in water infrastructure, are also increased by drought conditions.

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## EARTHQUAKE

Earthquakes have been described as shaking, ground-rolling vibrations caused by stress release along faults. Earthquakes can occur at any time of the year and may result in strong ground motion with a possibility of a ground surface rupture, slope failure (landslide or rockslide), and/or liquefaction. These factors can lead to a particularly destructive effect from this hazard. Even minor earthquakes can cause critical damage and loss of life.

### Surface Rupture

Surface rupture is caused by the differential movement of two sides of a fault and ultimately expressed at the earth's surface. Linear structures such as railways, highways, pipelines, and tunnels built across active surface faults, are extremely susceptible to being damaged by earthquakes. Displacement along faults, both regarding length and width, varies but can be significant (e.g., up to 20 feet), as can the length of the surface rupture (e.g., up to 200 miles).

### Liquefaction

Liquefaction occurs when seismic waves pass through saturated granular soil, distorting its granular structure, and causing some of the empty spaces between granules to collapse. Pore-water pressure may also increase sufficiently to cause the soil to behave like a fluid (rather than a soil) for a brief period and cause deformations. Liquefaction causes lateral spreads (horizontal movement commonly 10-15 feet, but up to 100 feet), flow failures (massive flows of soil, typically hundreds of feet, but up to 12 miles), and loss of bearing strength (soil deformations causing structures to settle, tip or collapse).

### Earthquake energy

Earthquake energy, referred to as seismic activity, is commonly described in terms of magnitude and intensity. Magnitude (M) describes the total energy released, and intensity (I) subjectively describes the effects at a particular location. Although an earthquake has only one magnitude, its intensity varies by distance from the epicenter, sub-surface and surface materials (e.g., soil, bedrock), topography and building types. The intensity of an earthquake is also dependent on the directivity of the seismic waves generated by the fault; therefore, location with respect to the fault also determines the intensity.

Magnitude is a number that characterizes the relative size of an earthquake and is based on measurement of the maximum motion recorded by a seismograph. Several scales have been defined, but the most commonly used are (1) local magnitude (ML), which is commonly referred to as "Richter magnitude", (2) surface-wave magnitude (Ms), (3) body-wave magnitude (Mb), and (4) moment magnitude (Mw). The Mw scale is the most commonly used and is an expression of the total energy released from an earthquake. All magnitude scales should yield approximately the same value for any given earthquake with only minor variations. Intensity is a measure of how strong the shock was felt at a particular location and is expressed by the Modified Mercalli Intensity (MMI) scale. Peak ground acceleration (PGA) measures the rate of change of ground motion relative to the rate of acceleration due to gravity.

It is possible to approximate the relationship between PGA, the magnitude, and the intensity, as shown in Table 6. The relationships are dependent upon specifics such as the distance from the epicenter, depth of the epicenter, and type of surficial material. For example, an earthquake with 10% PGA would roughly correspond to an intensity of V or VI, a magnitude of 5.0-5.9, and

could be described as “felt by everyone, overturning unstable objects, and/or moving heavy furniture.”

**Table 6: Earthquake PGA, Magnitude and Intensity Comparison**

PGA ( %g)	Magnitude	Intensity (MMI)	Description (MMI)
<0.17	1.0 - 3.0	I	<b>I.</b> Not felt except by a very few under especially favorable conditions.
0.17 - 1.4	3.0 - 3.9	II - III	<b>II.</b> Felt only by a few persons at rest, especially on upper floors of buildings. <b>III.</b> Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
1.4 - 9.2	4.0 - 4.9	IV - V	<b>IV.</b> Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motorcars rock noticeably. <b>V.</b> Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
9.2 - 34	5.0 - 5.9	VI - VII	<b>VI.</b> Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight. <b>VII.</b> Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
34 - 124	6.0 - 6.9	VII - IX	<b>VIII.</b> Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. <b>IX.</b> Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
>124	7.0 and higher	X or higher	<b>X.</b> Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent. <b>XI.</b> Few, if any (masonry) structures remain standing. Bridges destroyed, rails bent greatly. <b>XII.</b> Damage total. Lines of sight & level are distorted. Objects thrown into the air.

Source: Wald, Quitoriano, Heaton, and Kanamori, 1999.

## HISTORY

There has been no federal and only one state disaster declaration related to earthquakes. The state declaration was for flooding that resulted from a 1979 Imperial Valley earthquake (see below). The southeastern and southwestern corners of the state have been subject to the greatest intensity earthquakes. The earthquakes affecting the southeastern corner have originated in Mexico. Most of the earthquakes felt in southwestern corner have originated in southern California and

northern Mexico. Northern Arizona earthquakes have most commonly occurred between Flagstaff and the Grand Canyon. The following are a few examples of significant historic earthquakes that have occurred in or significantly impacted the state:

- 2014 - An Mw 5.3 earthquake occurred southeast of Safford with thousands of aftershocks, including an Mw 4.0.
- 2010 - A magnitude 7.2 earthquake centered in Baja California, Mexico about 19 miles southeast of Mexicali. The earthquake was felt in the Yuma area and caused minor damage and relatively short power outages for residents in Yuma, Gadsden, and Somerton areas.
- 1979 - A magnitude 6.6 earthquake centered in the southern Imperial Valley near El Centro, California, sent earth wave ripples through the Yuma Valley area and caused minor flooding. This resulted in a state declaration.
- 1940 - A magnitude 7.1 Imperial Valley earthquake caused \$50,000 in damage in the Yuma area. Four water service lines were broken, and the irrigation system was badly damaged. In Somerton, roads were buckled and bridges were dislodged, and a major portion of the geologic floodplain area experienced liquefaction due to the elevated water tables and sandy soils. The tremors were also felt in Phoenix and Tucson (DuBois, et.al., 1980).
- 1910 - A series of 52 small earthquakes caused a construction crew in the Coconino Forest near Flagstaff to break camp and leave the area as boulders rolled down on the camp from nearby mountains. The shocks grew in intensity over a two-week period until September 24, when a magnitude 6.0 shock was felt throughout northern Arizona. Adobe houses were cracked, and some chimneys fell over (USGS, Sept. 12, 2003).
- 1906 - A magnitude 6.2 earthquake occurred in Flagstaff and was the first damaging earthquake documented to have centered within Arizona borders. The quake caused Flagstaff schools to shut down and was the first of a string of earthquakes to impact the northern area in the early 1900s (AzCentral.com, 2017).
- 1887 - The Sonoran earthquake caused significant destruction in southern Arizona towns, including Tucson, and was one of the largest earthquakes in North American history. At the time this earthquake occurred, there were only about 90,000 people living in the Arizona Territory. The epicenter was located approximately 100 miles south of Douglas, Arizona, along the Pitaycachi fault in Mexico, and caused great destruction and 51 deaths near its epicenter. The earthquake, estimated to be a magnitude 7.4, was so large that it was felt from Guaymas, Mexico to Albuquerque, New Mexico (DuBois & Smith, 1980; McGarvin, 1987; DEMA, March 1998; Bausch & Brumbaugh, May 23, 1994).

## PROBABILITY/EXTENT

Each year, the Arizona Broadband Seismic Network seismometers record hundreds of earthquakes in Arizona, however, most of these events are low magnitude earthquakes that are generally not felt and do not produce damages. Accordingly, for much of the state, the probability of a damaging earthquake occurring is low to medium. The exception to this is the extreme southwest corner of the state (Yuma area), which has a greater probability of being



damaged by an earthquake due to the proximity of the high hazard seismic areas and active faults located in California and northern Mexico.

In 2014, the USGS updated the national seismic hazard maps (Peterson, et.al., 2014) for the conterminous United States<sup>1</sup>. One of the products included with the data are what the USGS calls scenario ShakeMaps<sup>2</sup>. A scenario ShakeMap is a predictive tool that represents the potential of a future earthquake by assuming a particular magnitude, epicenter location, and fault-rupture geometry, and estimating shaking intensity and magnitudes using a variety of strategies. The scenario locations were chosen to represent the areas with the highest probability of seismic activity.

The Arizona Geological Survey (Pearthree and Bausch, 1999) prepared a map depicting earthquake hazard zones in Arizona using historic seismicity, damages, and proximity to active or young faults. Four categories of hazard (High, Moderate, Moderate-to-Low, and Low) were developed.

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## WARNING TIME

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Warning time for earthquake events is essentially none, although some large magnitude events may be preceded by multiple, small-magnitude warning tremors.

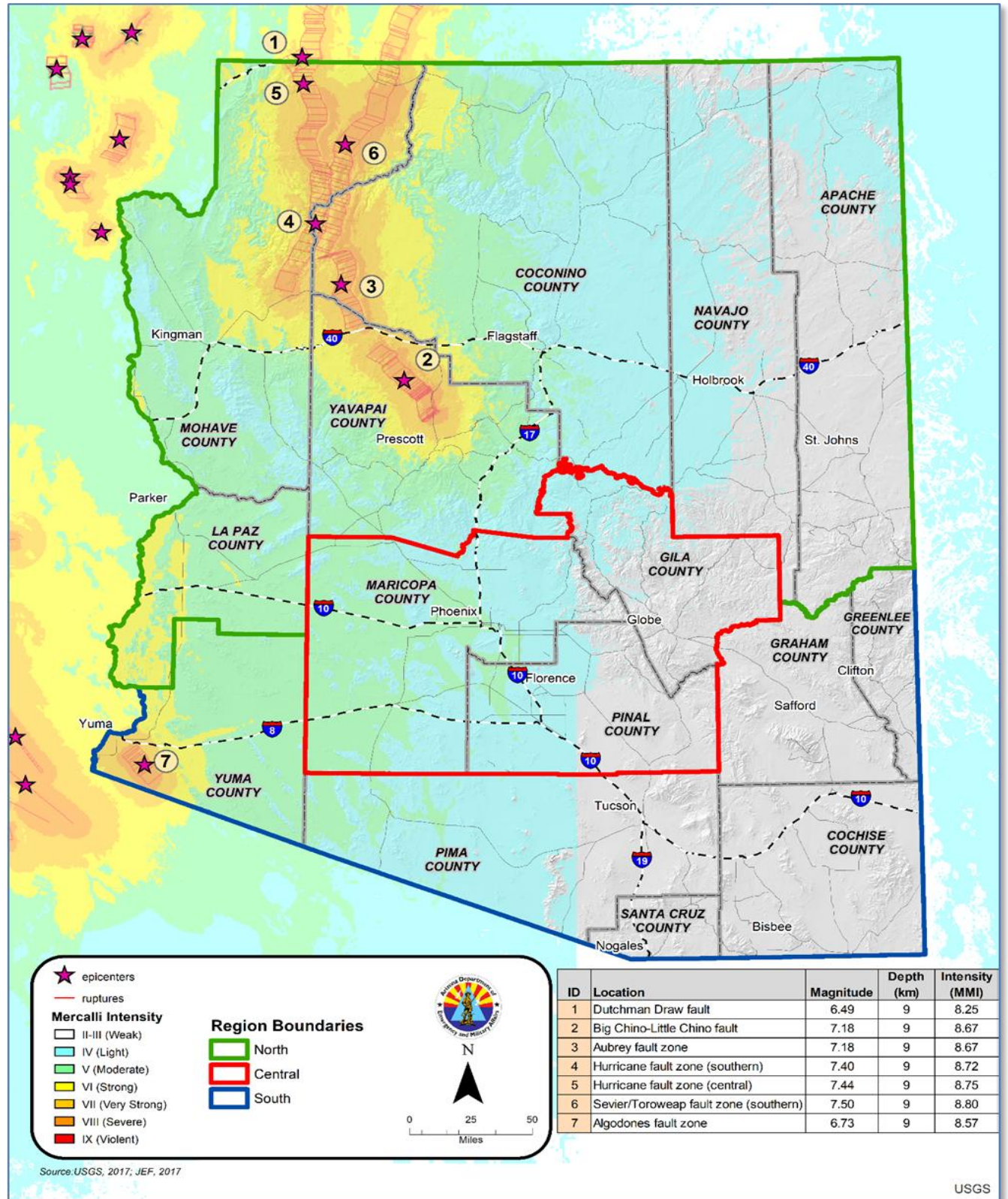
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<sup>1</sup>It is noted that several of the Flagstaff earthquakes were not all included in the USGS update and the one or two that were included is mis-located on the Navajo Reservation, many kilometers from the location determined by Bausch and Brumbaugh.

<sup>2</sup> USGS Earthquake Scenario Map (BSSC 2014),  
<http://usgs.maps.arcgis.com/apps/webappviewer/index.html?id=14d2f75c7c4f4619936dac0d14e1e468>

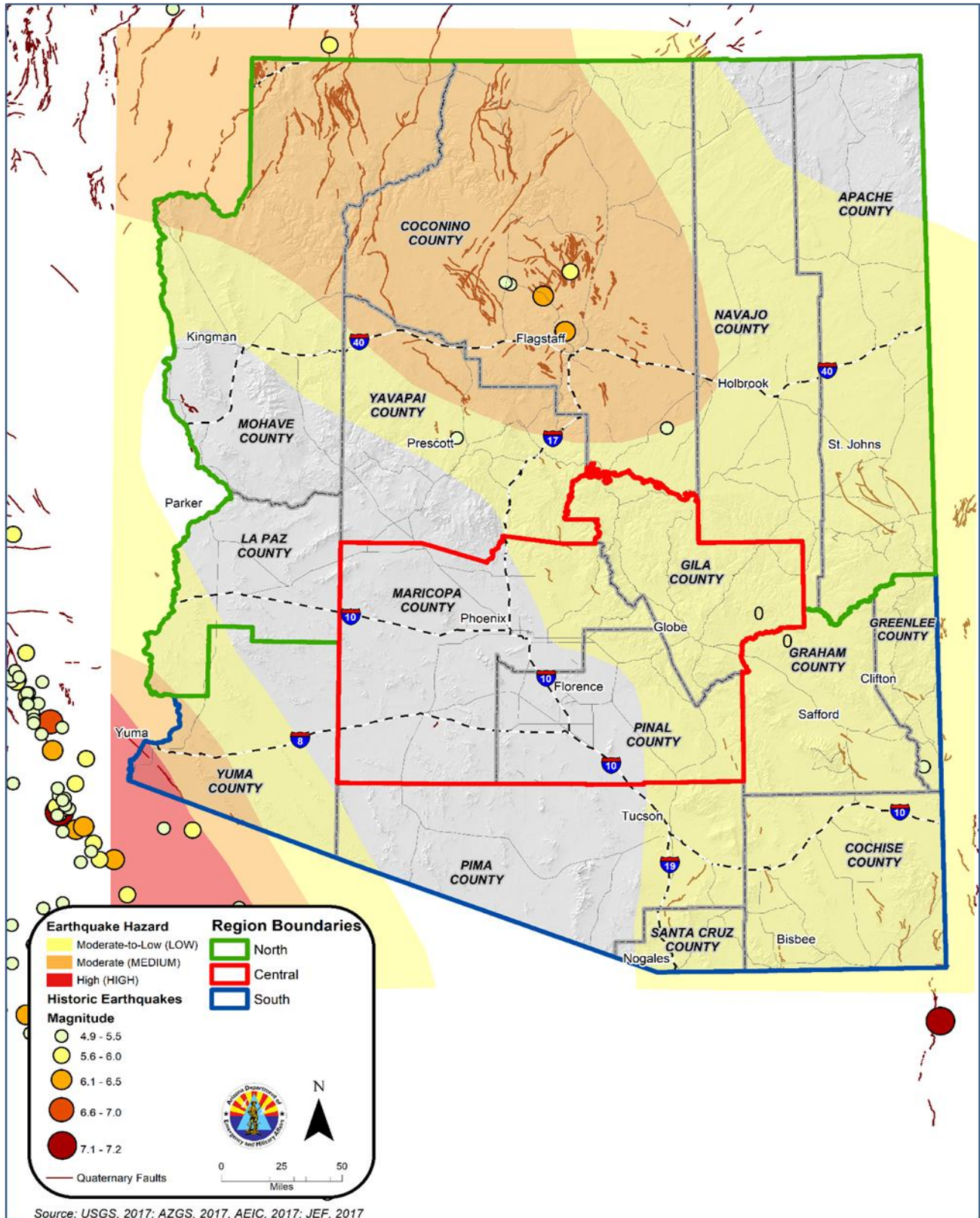


Map 6: Earthquake Scenario for Arizona

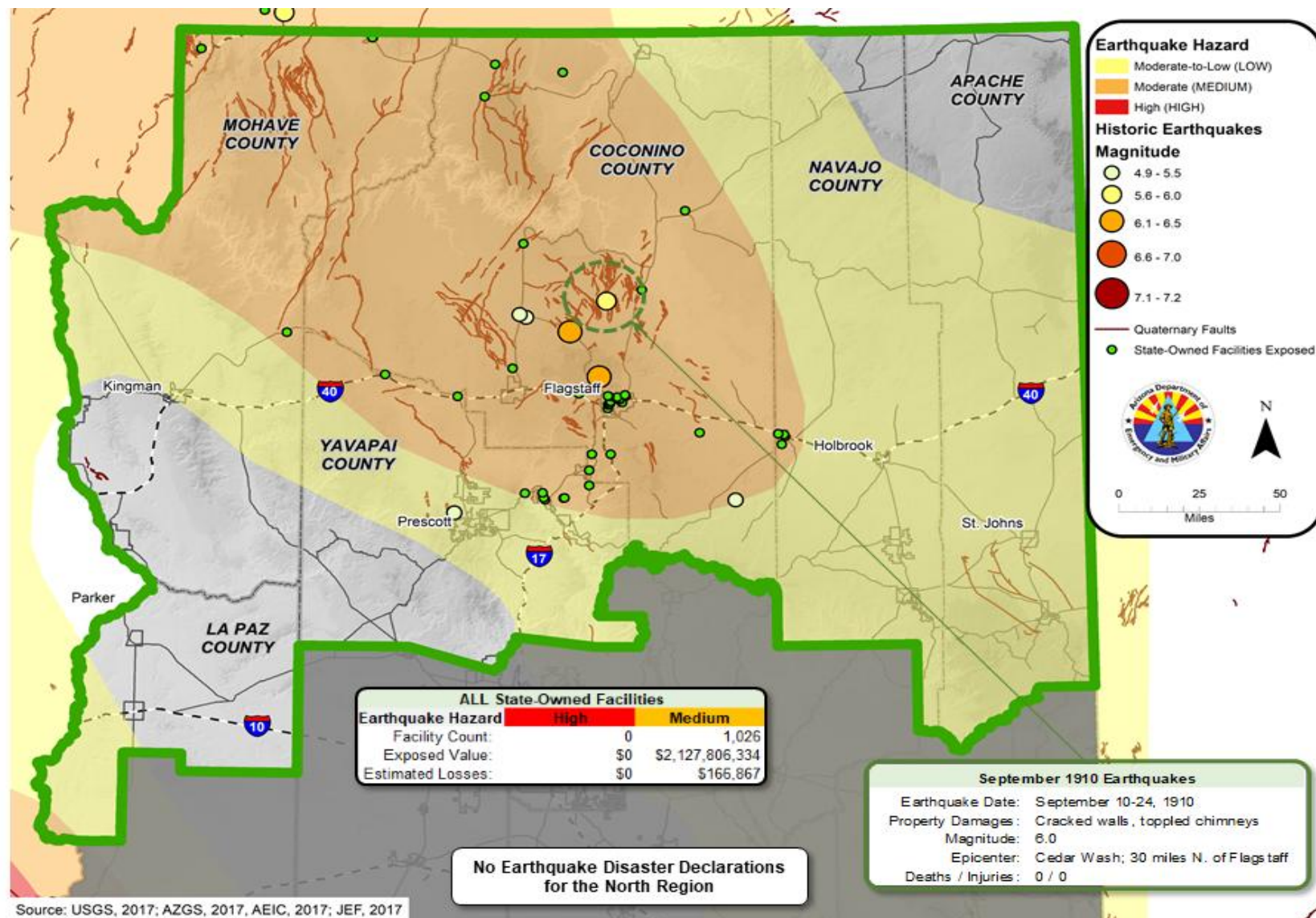




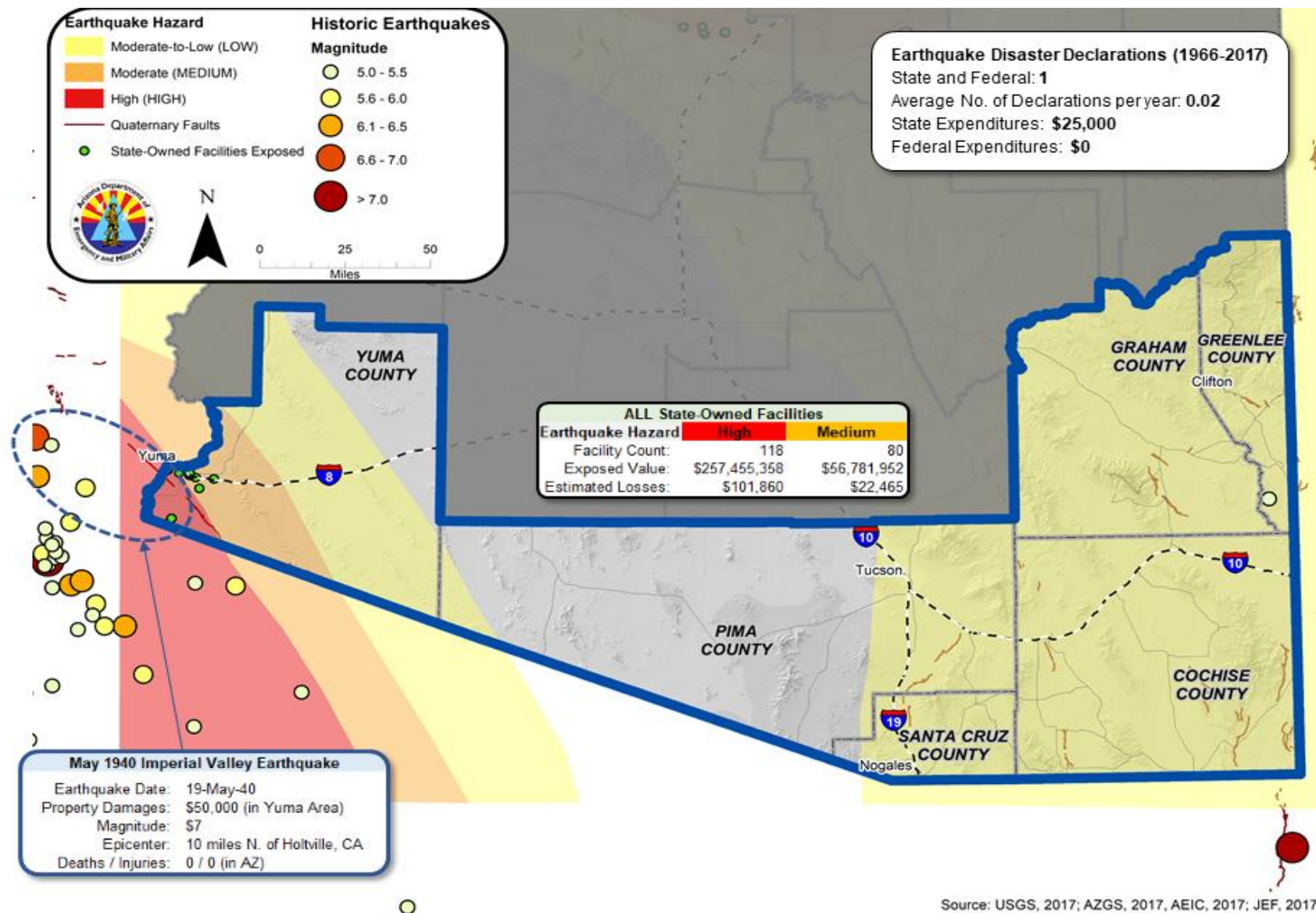
**Map 7: Earthquake Hazard Statewide**



**Map 8: Earthquake Hazard for North Region**





**Map 9: Earthquake Hazard for South Region**

## **FUTURE CONDITIONS**

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### **Climate Considerations**

The impact of climate change on earthquakes in Arizona is negligible. There has been some speculation that rises in sea levels are changing pressure and weight distribution around fault areas and may have the potential to trigger seismic activity along faults located near coast-lines. The translation of those impacts to Arizona seismic activity has not been established in the current literature.

### **Changes in Development**

Development increases in all areas of the state will increase the exposure and risk associated with earthquake events. It is likely that most of the development will be located near urbanized and metropolitan areas. Jenny and Reynolds (1989) noted that if an earthquake of similar magnitude to the 1887 Sonoran event were to occur under the presently developed conditions, the damages to southeastern Arizona communities, both population and infrastructure, would be extensive.

## **VULNERABILITY ASSESSMENT**

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Vulnerability to earthquake hazards for this Plan are estimated using the Pearthree (1999) hazard zones and recently developed average annual building loss rates<sup>1</sup> developed by FEMA using the HAZUS® program (FEMA, 2017) and the recent 2014 national seismic hazard data developed by the USGS (Peterson, et.al., 2014). The estimation of potential exposure to the identified high and medium earthquake hazard zones was accomplished using GIS tools to intersect the human and state-owned critical facilities and infrastructure (CFI) data with the earthquake hazard limits depicted the statewide profile map. No losses or exposure estimates are made for assets located in the medium-to-low and low earthquake hazard areas.

There are only three counties (Cochise, Coconino, and Pima) that included earthquake as a significant hazard in their local county risk assessments.

### **North Region**

The North Region is the second-most vulnerable region of the state, primarily due to the elevated earthquake hazard, number of young faults, seismic history, and population at risk.

#### **State-Owned CFI Exposure and Loss Estimates**

745 state-owned CFI, 95.5% of the total statewide medium hazard exposure, are located in the North Region. The exposed facilities represent total replacement values \$335.2 million, with an estimated \$22,863 in potential average annual losses.

Additional state-owned facilities vulnerable to earthquakes are the Arizona Department of Transportation (ADOT) operated and maintained freeways, highways and state routes,

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<sup>1</sup> Loss rates are published by county and are a dollar of loss per million dollars of replacement cost.

including the numerous bridges and culverts. Typical impacts might include pavement cracking and displacement, structure cracking, miss-alignments, and potential bridge failure.

### **Vulnerable Population Groups**

The 2015 estimated total population for the North Region is 772,157 people. Approximately 205,985 persons, 26.68% of the total population, are located within the medium earthquake hazard areas.

On average, approximately 7.3% of the North Region population is estimated to have a Limited English Proficiency (LEP) (US Census Bureau, 2016). Assuming the percentage is equally applied across the whole region's population, roughly zero and 15,036 LEP persons (7.3% or 205,985) are estimated to be located within the medium earthquake hazard areas.

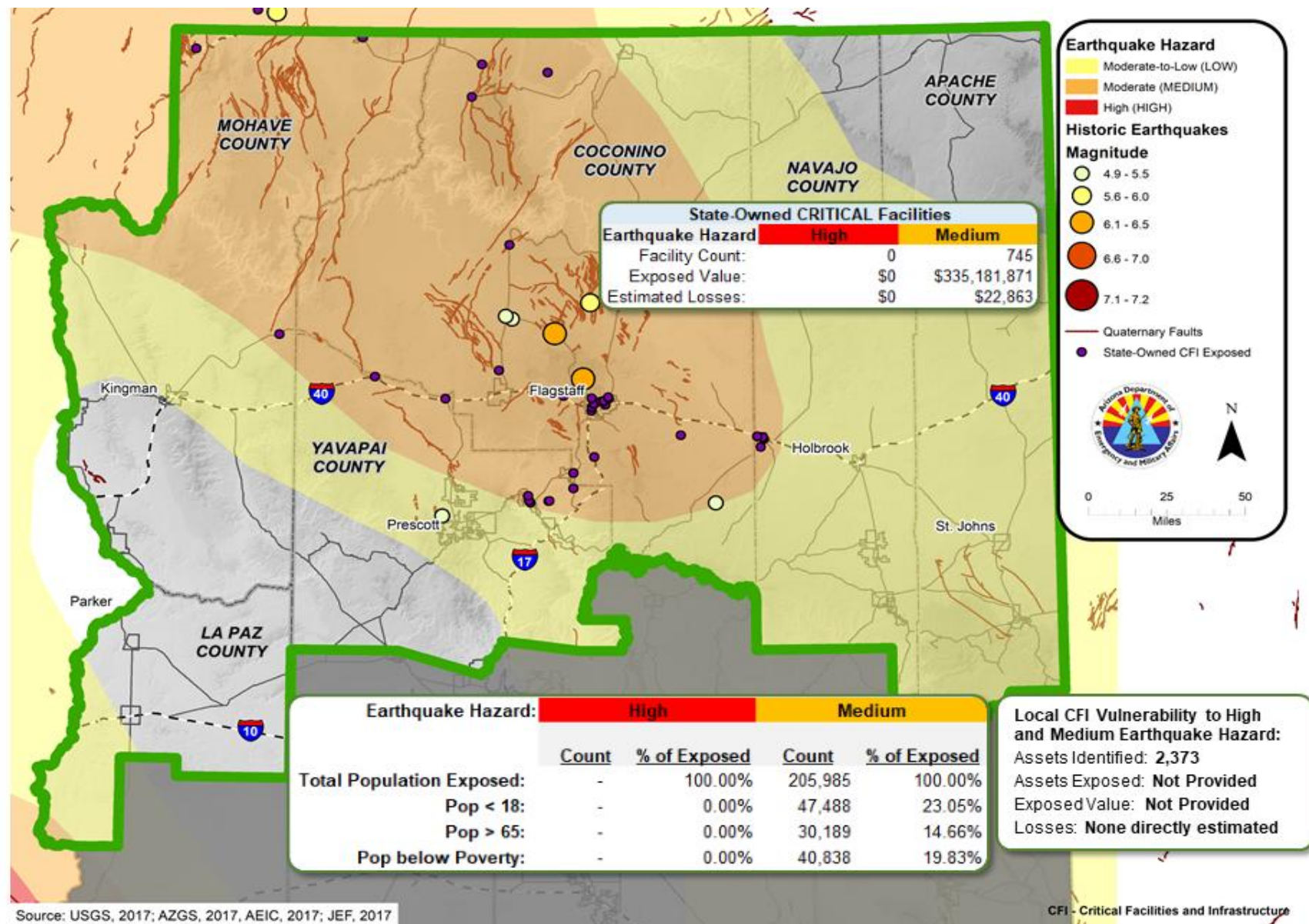
### **Local Jurisdiction Vulnerability**

None of the local jurisdictions in the North Region estimated earthquake related losses for locally identified critical and non-critical facilities. Discussions focused on disruption to transportation and major utility corridors, and potential damage to local water and wastewater infrastructure.

### **Specific Areas of Concern**

There are several small dams located in areas upstream of significant population centers that would likely not survive a significant ground shaking event. Failure of these structures would both create a significant floodwave and cause a significant loss of surface water for municipal use. For example, Lake Mary Reservoir is constructed along an active fault graben and provides the City of Flagstaff with a significant portion of its potable drinking water. Activation of the fault could destroy the reservoir, release floodwaters downstream and cause a significant loss to Flagstaff water supplies. Failures or significant damage to major interstate and rail transportation corridors would be economically crippling as well.



**Map 10: Earthquake Vulnerability for North Region**

## Central Region

The Central Region is the least vulnerable region in the state, largely due to a low earthquake hazard and essentially no significant seismic activity in the last couple of centuries. No vulnerability map is provided for the Central Region.

### State-Owned CFI Exposure and Loss Estimates

None of the state-owned CFI is located within a high or medium earthquake hazard zone and no losses are estimated.

### Vulnerable Population Groups

None of the 2015 estimated population of 4,604,414 people is located within a high or medium earthquake hazard area. This extends to all of the sub-population groups of under 18-years of age, older than 65, poverty level, and LEP.

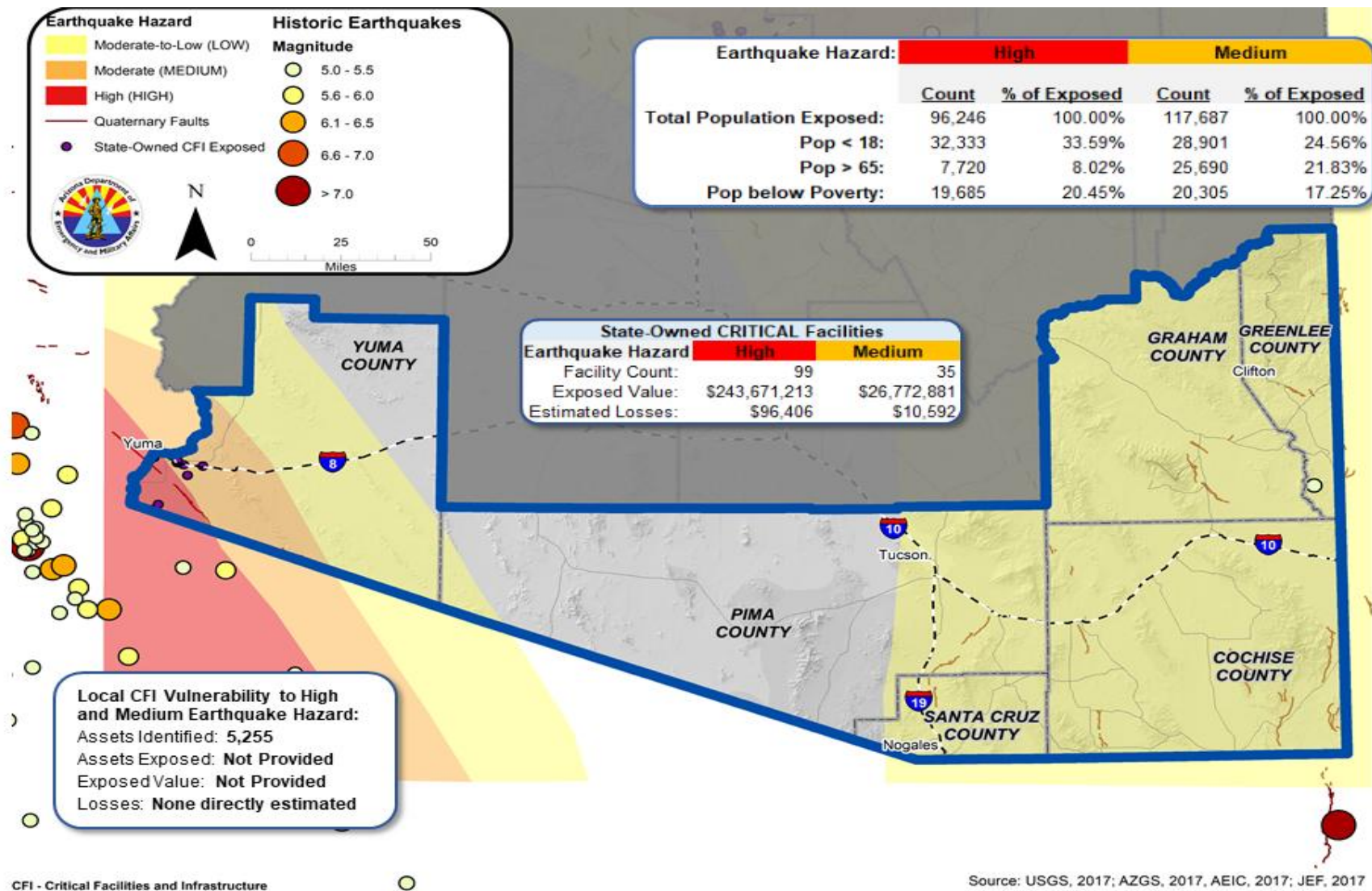
### Local Jurisdiction Vulnerability

None of the local jurisdictions in the Central Region considered earthquake as a significant hazard in their risk assessments. Accordingly, no local critical and non-critical facilities loss estimates were done.

### Specific Areas of Concern

Should a significant earthquake occur in or near the Phoenix Metropolitan Area, the losses and damages could be catastrophic. However, the probability of such an occurrence happening is very low.

Map 11: Earthquake Vulnerability for South Region



## South Region

The South Region is the most vulnerable region in the state. This is largely due to the high risk associated with the elevated levels of seismic activity, active faults, a history of strong earthquakes in the nearby Imperial Valley and Baja California areas, and their impacts on the extreme southwest corner of the South Region. Most of the Yuma County population centers are located within a high or medium earthquake hazard area.

### State-Owned CFI Exposure and Loss Estimates

A total of 99 and 35 state-owned CFI, or 100% and 4.5% of the statewide exposure, are located within a high or medium hazard area. The exposed facilities represent total replacement values of \$243.7 million and \$26.8 million, with estimated \$96,406 and \$10,592 in potential average annual losses. Additional state-owned facilities vulnerable to earthquakes are ADOT operated and maintained freeways, highways and state routes, including numerous bridges and culverts. Typical impacts include pavement cracking and displacement, structure cracking, miss-alignments, and potential bridge failure.

### Vulnerable Population Groups

The 2015 estimated total population for the South Region is 1,458,367 people. Approximately 6.60% and 8.07% of the total regional population, or 98,246 and 117,687 persons, are located within the high and medium earthquake hazard areas.

On average, 12.7% of the South Region population is estimated to have Limited English Proficiency (LEP). Assuming the percentage is equally applied across the region's population, roughly 12,477 and 14,946 LEP persons (12.7% of 98,246 and 117,687) are estimated to be located within the high and medium earthquake hazard areas.

### Local Jurisdiction Vulnerability

Cochise County performed a standard event based HAZUS® analysis assuming a magnitude 6.9 earthquake near the historic epicenter of a 1939 earthquake near Duncan. The general building related losses were estimated at \$3.5 million with over 70% being attributed to residential structures. The total economic loss was estimated at \$3.7 million. Losses to local CFI were not appreciable. Pima County also reported the use of HAZUS® to generate average annualized amounts of approximately \$2.3 million in combined residential and commercial losses for the county. No mention is given to local CFI exposure or losses. None of the other South Region counties included earthquake in their risk assessments.

### Specific Areas of Concern

The relatively shallow groundwater table and sandy loam soils that dominate the Yuma and Gila Valley areas adjacent to the Colorado and Gila Rivers, pose a significant risk to seismically induced liquefaction zones. Damages to agricultural resources and infrastructure by liquefaction could prove economically catastrophic if a seismic event were to occur during the peak of the growing season. Historic mining and tunneling below Tombstone, Douglas, Nogales, and San Luis pose a seismic risk, in that if an event were to occur, it could trigger a collapse of known and unknown subsurface cavities and tunnels in the area.



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## POTENTIAL CONSEQUENCES AND IMPACTS

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### Public

For a large area of the state, the relatively low probability of damaging earthquakes does not pose a significant threat to the people located in those areas. In the higher risk areas, deaths or injuries are more feasible, and especially in the areas with a past of frequent significant events. Injuries may occur by falling or collapsing materials, broken glass, and damaged infrastructure such as fallen power lines, gas line leaks, fires, HazMat spills, etc.

### Property/Facilities/Infrastructure

Structures and buildings constructed before enforcement of modern building codes are significantly more susceptible to seismic activity. Surface infrastructure such as irrigation systems, roads, bridges, power lines, pipelines, and other rigid structures are vulnerable to damage. Buried pipelines and utilities are also vulnerable, especially around fault zones.

### Responders

Response requirements to potential earthquake incidents in the higher risk areas will likely be limited, and the greatest impacts posed to responders would be exposure to aftershocks, potential hindrance due to lifeline damages, and possible exposure to hazardous materials that were spilled during an event.

### Continuity of Operations/Delivery of Services

In the elevated seismic risk areas of the state, it is unlikely that an earthquake event would render critical facilities and infrastructure useless. A moderate disruption of local services may be experienced in a large magnitude event but would not be expected to last longer than a few days. A larger threat would involve a catastrophic earthquake in Southern California which could likely result in a disruption to the flow of fuel and food goods as well as a likely significant influx of people to the state.

### Environment/Cultural

Environmental impacts from a significant seismic event could include the manifestation of a permanent surface rupture through the differential movement of two sides of a fault at the earth's surface. Displacement along faults, both in terms of length and width can vary. Earthquake-related ground failure due to liquefaction and potential landslides and rock falls, are known to cause significant damage in areas affected by earthquakes. For example, an earthquake event in the Yuma area may impact the environment in the form of hazardous material spills resulting from building and infrastructure failures due to either ground shaking or liquefaction. Landslides and the collapse of subsurface voids may result in both environmental and cultural impacts. For instance, the Town of Tombstone is positioned over large cavities created by mining operations and then abandoned. Many historic buildings in the Tombstone area would be instantly destroyed should the mining caves collapse.

### Economic/Financial Condition of Jurisdiction

It is unlikely that an event would cause enough damage to significantly impact the economy or financial condition statewide. Especially since the largest base of economic activity (the Phoenix

and Tucson Metropolitan Areas) is located in a low earthquake risk area. In the elevated risk areas, local economies may be more significantly impacted due to potential damages to surface water reservoirs, residential and commercial buildings, and the resulting financial hardship for homeowners and business owners alike. Businesses that are affected to the point of lost revenue may be forced to reduce staff or close or relocate their business, which would result in declined employment. Destruction of agricultural systems and crops could also have a devastating impact on a local economy.

### **Public Confidence in Jurisdiction's Governance**

Most of the earthquake potential for the state is located in the less populated areas, and a significant earthquake in those areas is not expected to lessen the public's confidence in a government's ability to govern. Local jurisdictions may experience hindered governance if an event of large magnitude were to occur. In those rare occasions the public's confidence may be eroded slightly, but not significantly.

### **Cascading/Secondary Impacts**

Cascading events associated with moderate to large-magnitude earthquakes are numerous, disparate, and could be catastrophic. Examples include landslides, dam and levee failures, bridge failures, lifeline disruptions, road and rail transportation accidents, flood risk due to altered flowpaths, fires, hazardous materials spills, and continuing seismicity due to aftershocks and activation of other fault systems.

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US Geological Survey – Earthquake Hazards Program, <https://earthquake.usgs.gov/>

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## EXTREME HEAT

Extreme Heat is very high temperatures that are possibly combined with exceptionally humid conditions. The worst extreme heat events span several days, with one or more near record or record-breaking temperatures. The significant human risks associated with extreme heat are:

### Heat Cramps

May occur in people unaccustomed to exercising in the heat and generally ceases to be a problem after acclimatization.

### Heat Syncope

This refers to the sudden loss of consciousness and is typically associated with people exercising who are not acclimated to warm temperatures. It usually causes little or no harm to the individual.



### Heat Exhaustion

While much less serious than heatstroke, heat exhaustion victims may complain of dizziness, weakness, or fatigue. Body temperatures may be normal or slightly/moderately elevated. The prognosis is usually good with fluid treatment and removal from heat.

### Heatstroke

Heatstroke is considered a medical emergency and is often fatal. It occurs when the body's responses to heat stress are insufficient to prevent a substantial rise in the body's core temperature. While no standard diagnosis exists, a medical heatstroke condition is usually diagnosed when the body's temperature exceeds 105°F due to environmental temperatures. Rapid cooling is necessary to prevent death, with an average fatality rate of 15% even with treatment.

In addition to affecting people, extreme heat places significant stress on plants and animals leading to reduced agricultural yields and increased mortality rates.

## HISTORY

Extreme high temperatures occur in Arizona on a regular basis, but the highest threat typically occurs during the summer months of June to August when monsoon moisture raises the heat index. There are no state or federal declarations for extreme heat events. Below are some notable events that were either record breaking or have occurred over the last five-years:

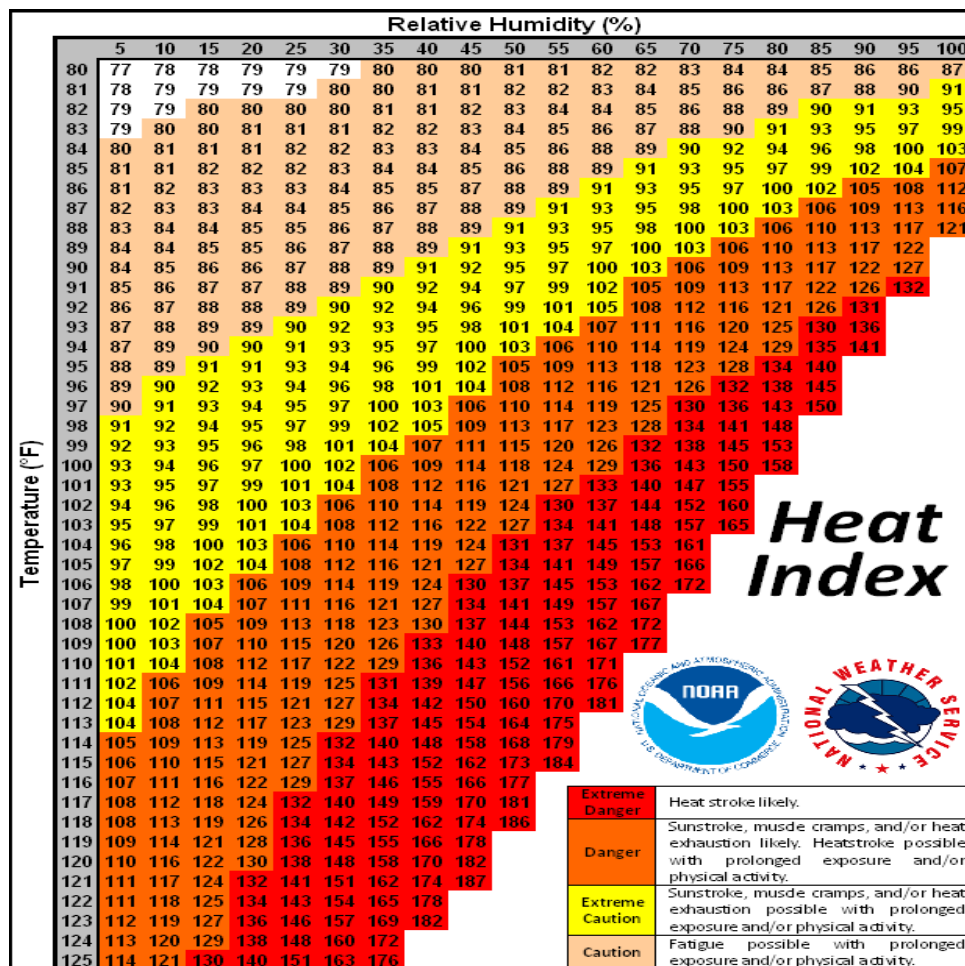
- June 2016 - High temperatures over a four-day period (3<sup>rd</sup>-6<sup>th</sup>) in eastern Pima County contributed to 14 serious heat-related illnesses. Heat broke records ranging from 107°F to 111°F (NCEI, 2017). A second heat wave hit between June 18<sup>th</sup> -20<sup>th</sup> causing four heat-related deaths ranging in age from 19 to 57 years. A temperature in Tucson was recorded at 115°F marking the third highest temperature ever recorded.

- August 14-16, 2015 - Extreme heat caused 36 heat-related illnesses, including 12 in metropolitan Tucson, 12 in western Pima County and 12 on the Tohono O'odham Nation. Temperatures reached 115°F between August 14 and 16 in south-central and southwestern Arizona. Record high temperatures were set at Tucson, Ajo, Organ Pipe National Monument, and Picacho Peak State Park. High electricity demand caused power outages in the Tucson area for 1,700 customers (NCEI, 2017).
- From 2006 to 2013 - There were 632 confirmed deaths attributed to excessive natural heat in Maricopa County, with 106 and 110 of those deaths occurring in 2011 and 2012, respectively (MCDPH, 2014). The overwhelming majority of those deaths occurred during the hot summer months of June, July, and August.
- June 29, 1994 - Arizona's highest recorded temperature of 128° F was set in Lake Havasu City.

## PROBABILITY/EXTENT

Given the history of past extreme heat events (EHEs), the probability of EHEs occurring somewhere in the state is very high, and for the lower elevation Sonoran and Mohave Desert areas (generally below 2,500 feet in elevation), a near certainty.

**Figure 4: Heat Index Chart**



The extreme heat hazard has the potential to be severe due to the number of individuals affected by the hazard, health impacts that can lead to death, and increasing number of days of extreme heat each year. An indicator of the degree of danger associated with extreme heat is the heat index. According to the NWS, the heat index is a measure of how hot it really feels when relative humidity is accounted for. It should be noted that the heat index values shown were devised for shady, light wind conditions and that exposure to full sunshine can increase heat index values by up to 15°F. In addition, strong winds, particularly with very hot, dry air, can be extremely hazardous and not accounted for in the heat index danger.

## WARNING TIME

Warning time for most EHEs can be measured in a couple of days to one-week. In a broader, seasonal sense, Arizona residents that live in the lower Sonoran and Mohave Desert areas generally understand that temperatures can exceed 100°F as early as April and will continue hot through September and even October.

The National Weather Service (NWS) Warning and Forecast Office (WFO) in Phoenix, with the technical support of the University of Maryland, designed a science-based, customized, extreme heat index system developed specifically for the Phoenix Metropolitan Area. During Arizona's hottest months, the NWS WFO in Phoenix issues three types of heat-related messages, they are described below:

### Heat Advisory

Issued when the temperature is forecast to be unusually hot but not life-threatening.

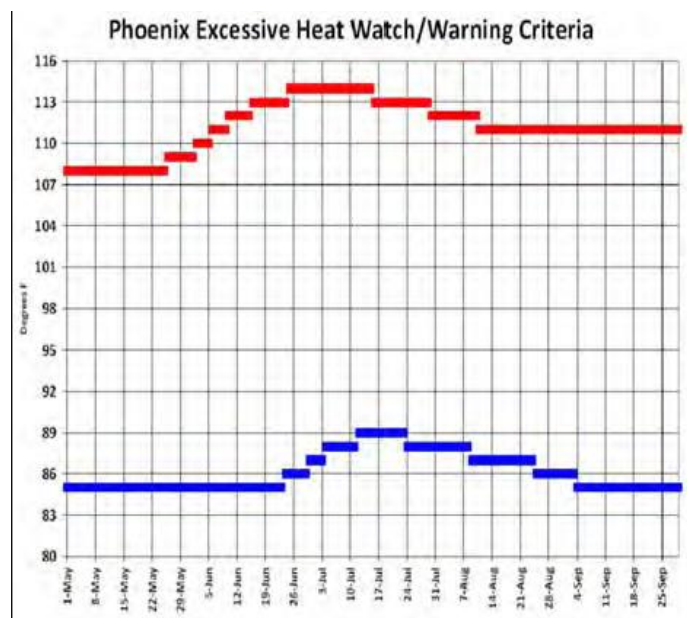
### Excessive Heat Watch

Issued when conditions are likely to result in a life-threatening heat emergency within the next 24-48 hours.

### Excessive Heat Warning

Issued when a life-threatening heat emergency exists or is imminent. The issuance of a message is based on assessment of four factors; temperature, humidity, amount of cloudiness, and the expected duration of these conditions. The temperature component also includes a seasonal evaluation of the maximum *low* temperature as well as the maximum *high* temperature. These products are intended to raise the public's awareness and mitigate heat illnesses from occurring. The table below shows the maximum and minimum excessive heat threshold values determined for the Phoenix Metropolitan area as published by the NWS Phoenix WFO.

Figure 5: Excessive Heat Watch/Warning Criteria





## FUTURE CONDITIONS

The Arizona Department of Health Services (ADHS) and Arizona State University (ASU) jointly prepared the Arizona Extreme Weather, Climate and Health Profile Report (Chuang, et.al., 2015), which was the first step in looking at how future extreme heat events and changes in air pollution might affect the health of Arizona's vulnerable populations and suggesting possible ways for adapting to those changes. According to death statistics reported by Chuang, et.al. (2015), the majority of EHEs occur during the month of July when temperatures are highest, and the state begins to experience the onset of monsoon moisture. Figure 6 presents the projected increase in average July maximum temperature for the year 2030 (1981-2010).

### Climate Considerations

Most of the current science and literature generally acknowledge and anticipate a warming trend over the next several decades. The magnitude of temperature increases varies with the assumption of emissions concentrations<sup>1</sup> over the next 50-60 years. Chuang, et.al. (2015) indicated that the largest temperature changes are likely to occur in Arizona's more rural north and northeastern areas. Average maximum July temperature projections for 2030 show increases between 0.5°F and 4.7°F.

**Figure 6: Temperature Increase Projections**

County	RCP 2.6		RCP 4.5		RCP 6.0		RCP 8.5	
	2010	2030	2010	2030	2010	2030	2010	2030
Apache	88.5	3.1	89.1	1.9	87.3	3.7	90.5	2.3
Coconino	90.5	4.1	91.1	1.4	89.3	3.2	92.5	1.8
La Paz	94.5	3.9	95.1	2	93.3	1.5	96.5	0.7
Mohave	96.5	4.7	97.1	1.2	95.3	2.9	98.5	1.2
Navajo	97.5	3.6	98.1	1.8	96.3	3.6	99.5	2
Yavapai	101.5	4.1	102.1	1.7	100.3	2.5	103.5	1.1
Gila	91.5	3.6	92.1	2	90.3	2.7	93.5	1.5
Maricopa	95.5	4.1	96.1	1.8	94.3	1.8	97.5	0.5
Pinal	99.5	3.8	100.1	1.8	98.3	2	101.5	0.9
Cochise	89.5	3.2	90.1	2	88.3	1.8	91.5	1.8
Graham	92.5	3.4	93.1	1.8	91.3	2.3	94.5	1.8
Greenlee	93.5	3.4	94.1	2	92.3	2.5	95.5	1.9
Pima	98.5	4	99.1	2	97.3	1.6	100.5	0.7
Santa Cruz	100.5	3.3	101.1	1.8	99.3	1.5	102.5	1.1
Yuma	102.5	4	103.1	2.6	101.3	1.4	104.5	0.7

**Note:** RCP - Representative Concentration Pathways  
Projected Increases in Average July Maximum Temperatures for 2030 for Various Emission Scenarios  
Adapted from Chuang et.al., 2015

### Changes in Development

Development related changes impact extreme heat by increasing the probability and magnitude of the hazard. Expansion of urban footprints and associated heat reflecting and generating mechanisms all can contribute to increases in maximum temperatures if the concentrations are dense enough. Population growth increases the risk of injury or deaths associated with EHEs, especially in urban areas.

#### North Region

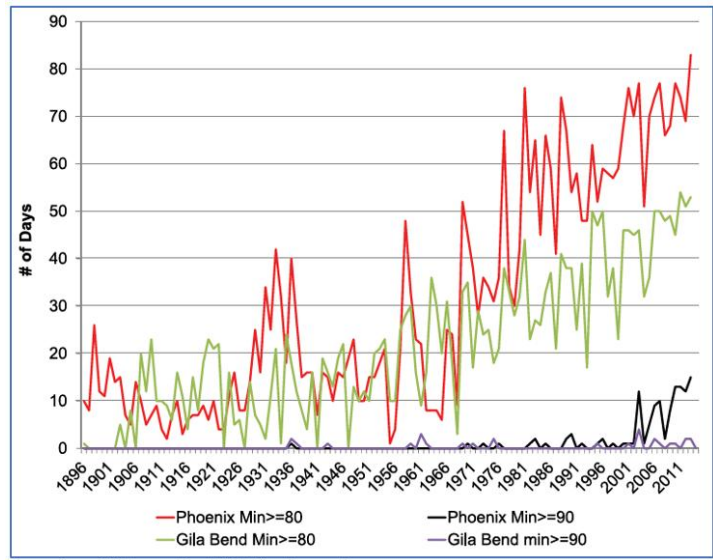
Development related changes for most communities in the North Region are expected to be low based on reports from the local county hazard mitigation plans. The majority of the anticipated growth is expected to expand from the existing cities and towns. The areas with the most significant extreme heat exposure are La Paz and western Mohave Counties.

<sup>1</sup> The report refers to the modeled scenarios as representative concentration pathways or RCPs.

### Central Region

Over the past 60 years, the Metropolitan Phoenix area has been among the fastest-growing urban areas in the United States. This expansion of impervious surface and other heat producing/storing mechanisms has resulted in an urban heat island (UHI) of substantial size and intensity. According to Chow, et.al. (2012), from 1948-2000 urbanization has increased the nighttime minimum temperature in central Phoenix (Sky Harbor International Airport) by approximately 9°F and the average daily temperature by approximately 5.5°F. Another telling statistic is the number of 100-degree days registered in the Phoenix area. In 1913, Phoenix had 48 days that were over 100°F, and the average now is 109 days. A third impact from the increased UHI footprint is the increase in the number of days in which the minimum nighttime temperatures are above 90°F, which can be detrimental to population sectors without access to air conditioning. Continued growth in these areas will further expand the UHI and its impacts.

**Figure 7: Nighttime Temps, Urban and Rural**

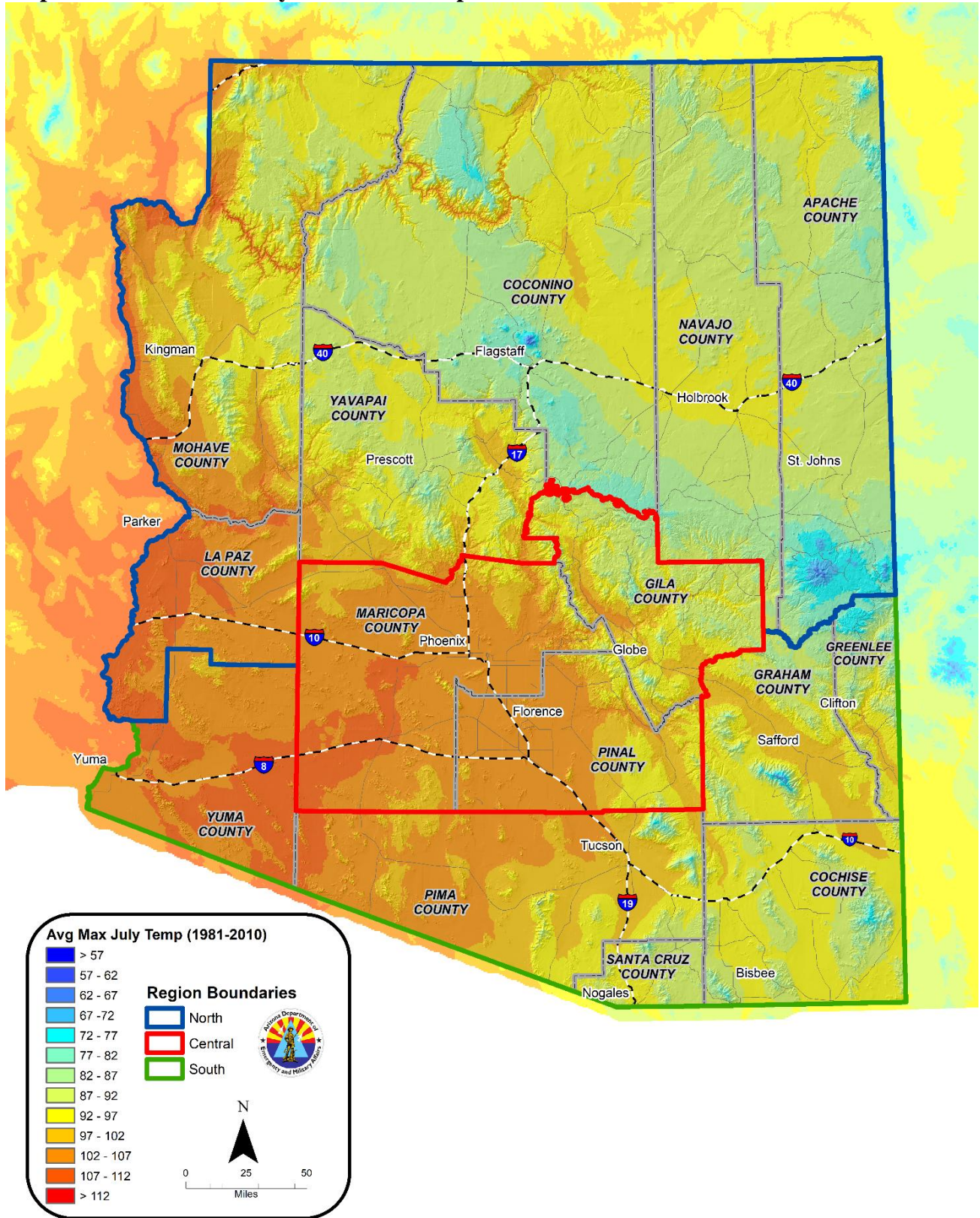


### South Region

Similar to the Central Region, the Tucson Metropolitan area has grown significantly over the last 50 years, with urban temperatures being about 5.5°F warmer than they were in the last century and noting that 3.5°F of the warming occurred in the previous 30 years. The most significant development anticipates for the South Region is expected to primarily occur in the Tucson Metropolitan Area, which will continue to expand the UHI footprint. Other areas of the South Region are not anticipating significant growth.



**Map 12: Extreme Heat July Maximum Temperatures**

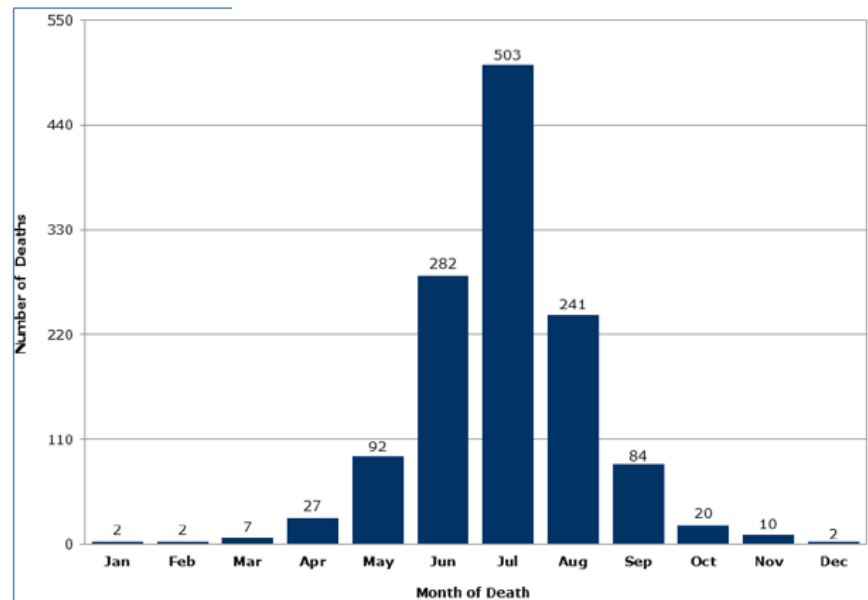


## VULNERABILITY ASSESSMENT

In many parts of the state, extreme heat occurs as a chronic, rather than episodic, hazard with dangerously high temperatures persisting throughout the warm season (Harlan et al. 2014). Continual high nighttime lows do not allow the body to recover from the daytime heat, if no access to cooling is available. The worst impacts of EHEs will likely be felt in urban areas, where large numbers of vulnerable people reside, urban heat island effects exist, and air quality is likely to be poor (Revi et al. 2014). Chuang, et.al. (2015) notes that human vulnerability to heat involves more than physical exposure to extreme heat events. It also involves individual and population sensitivity to EHEs and adaptive capacity. Sensitivity depends on the underlying characteristics of a population, such as age and ethnicity. Adaptive capacity reflects the capability of a system, population, or individual to cope with changes. The homeless are particularly vulnerable to EHEs during the summer months when the increased humidity and urban heat island effects keep nighttime temperatures above 90°F for prolonged periods. The cumulative effects over several days of continuous 24-hour exposure to this heat, without relief, put these individuals at serious risk of heat stress or worse. Others at significant risk are the low-income populations who do not have air conditioning, or in many cases do not even have evaporative coolers. The lack of air conditioning means this population, like the homeless, are also lacking night time relief from the heat, elevating their risk of heat stress or other complications.

**Figure 8: Excessive Heat Deaths**

According to the Center for Disease Control, extreme heat is responsible for most weather-related deaths in the United States. Arizona has the largest number of heat related deaths in the nation (Brown et al., 2013). During 2005-2015, 1,272 deaths related to exposure to excessive natural heat occurred in Arizona. Extreme heat-related deaths and illnesses are so prevalent in Arizona because of the



Deaths from Exposure to Excessive Natural Heat occurring in Arizona by Month, 2005-2015

Source: Fig 3A from ADHS report (Sagna, et al., 2017)

consistent and increasing number of days with both high minimum and maximum temperatures. Arizona residents accounted for 536 deaths (42.1% of the total), or 49 deaths on average per year in 2005-2015. Migrants from Mexico, Central America, or South America accounted for 40.0% of the total deaths with the remaining 7.9% being attributed to other visitors.

Vulnerability and exposure of the state-owned facilities to EHEs are not significantly damaging in a direct way, but rather on a long-term maintenance basis to fix and repair heat related damages to HVAC systems, roofs, and other heat susceptible materials. No damages are estimated for state-owned facilities in this Plan.

## North Region

The North Region is considered the least vulnerable to EHEs due to the lower overall temperatures, higher densities of shade producing vegetation and reduced population densities. It is noted, however, that the Arizona strip communities along the Colorado River in La Paz and western Mohave Counties (Cibola, Ehrenberg, Parker, Parker Strip, Lake Havasu City, Bullhead City, and Mohave Valley) are actually some of the hottest locations within the state and are routinely the location of state record high temperatures. Approximately 7.0% of the total heat related deaths reported by ADHS for 2005-2015 are attributed to the North Region, and 45% of that attributed to La Paz and Mohave Counties.

### State-Owned CFI Exposure and Loss Estimates

All 1,988 state-owned facilities representing \$2.4 billion in replacement value are exposed to extreme heat. No losses are estimated.

### Vulnerable Population Groups

The entire 2015 estimated population of 772,157 people are considered to be exposed to EHEs, with the Arizona strip communities mentioned above having an elevated risk due to the significantly hotter temperatures. The exposed sub-group populations include 177,450 persons (23.0% of region total) under 18-years of age, 158,170 persons (20.5% of region total) older than 65, 163,483 persons (21.2% of region total) living at or below poverty level, and an ELP population of 56,625 (7.3% of region total).

### Local Jurisdiction Vulnerability

Mohave County is the only North Region county to address extreme heat in their mitigation plan risk assessment. Conclusions of the vulnerability analysis are similar to what is presented in this Plan.

### Specific Areas of Concern

According to the Mohave County mitigation plan, elevated demands on power supplies during EHEs in communities like Lake Havasu City and Parker, have resulted in past power failures during a time when air conditioning and other cooling needs are most critical.

## Central Region

The Central Region is considered the most vulnerable to EHEs due to the relatively high temperatures, lower densities of shade producing vegetation, the highest population density, and the significant impacts associated with urban heat island effects in the Phoenix Metropolitan area. Approximately 39.3% of the total heat related deaths reported by ADHS for 2005 to 2015 are attributed to the Central Region, and 88% of that is attributed to Maricopa County.

### State-Owned CFI Exposure and Loss Estimates

All 3,464 state-owned facilities representing \$9 billion in replacement value are exposed to extreme heat. No losses are estimated.



### Vulnerable Population Groups

The entire 2015 estimated population of 4,604,414 people are considered to be exposed to EHEs. The exposed sub-group populations include 1,216,158 persons (26.4% of region total) under 18-years of age, 618,612 (13.4% of region total) persons older than 65, 748,257 persons (16.3% of region total) living at or below poverty level, and an LEP population of 306,961 (6.7% of region total).

### Local Jurisdiction Vulnerability

Maricopa County is the only Central Region county to address extreme heat in their mitigation plan risk assessment. The Maricopa County mitigation plan notes the intensification of the urban heat island effects and a correlation to steadily increasing nighttime low temperatures on mortality rates. The plan also notes economic impacts of increased cooling costs and greater demand on power resources because of expansion of the urban footprint. Other conclusions of the vulnerability analysis are similar to what is presented in this Plan.

### Specific Areas of Concern

As previously stated, one of the impacts of EHE-caused mortality rates is tied to the urban heat island effects on the corresponding nighttime low temperatures. The combination of potential for future rising temperatures, combined with future growth and un-mitigated expansion of the urban footprint and increased populations, equals increased overall risk to the Phoenix Metropolitan area. The Mesa and Phoenix are the two largest cities and also have the largest homeless and poverty populations impacted. Buckeye, Queen Creek, and the adjacent San Tan Valley are the fastest growing municipal areas and illustrate the expansion of the urban footprint in both west and east directions.

## South Region

The South Region is considered the second-most vulnerable to EHEs due to the relatively high temperatures associated with the highest population centers, lower densities of shade producing vegetation, the moderately-high population density, and the significant impacts associated with urban heat island effects in the Tucson Metropolitan area. Approximately 54.1% of the total heat related deaths reported by ADHS for 2005-2015 are attributed to the South Region, and 79.7% of those are attributed to Pima County. However, according to a database created by Humane Borders and the Pima County Office of the Medical, it is noted that the majority contributor to those numbers are related to illegal immigration through the southern Arizona, US-Mexico border. The ADHS 2005-2015 report estimated approximately 509 migrant related deaths for the period, which accounts for the vast majority of the South Region deaths.

### State-Owned CFI Exposure and Loss Estimates

All 1,505 state-owned facilities representing \$5.2 billion in replacement value, are exposed to extreme heat. No losses are estimated.

### Vulnerable Population Groups

The entire 2015 estimated population of 1,458,367 people are considered to be exposed to EHEs. The exposed sub-group populations include 354,191 persons (24.3% of region

total) under 18-years of age, 242,700 (16.6% of region total) persons older than 65, 268,372 persons (18.4% of region total) living at or below poverty level, and an ELP population of 306,961 (6.7% of region total).

### **Local Jurisdiction Vulnerability**

Pima County is the only South Region county to address extreme heat in their mitigation plan risk assessment. The Pima County plan notes the intensification of the urban heat island effects in the Tucson Metropolitan area. The plan also notes economic impacts of treatment costs for extreme heat related illness, and the risk of greater demand on power resources. Other conclusions of the vulnerability analysis are similar to what is presented in this Plan.

### **Specific Areas of Concern**

As noted above, one of the impacts of EHE-caused mortality rates is tied to the urban heat island effects on the corresponding nighttime low temperatures. The combination of potential for future rising temperatures, combined with future growth and un-mitigated expansion of the urban footprint and increased populations, equals increased overall risk to the Tucson Metropolitan area.

## **POTENTIAL CONSEQUENCES AND IMPACTS**

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### **Public**

Impacts to public health and safety are the most prominent consequence of an extreme heat event. Sickness and death can occur under certain circumstances without the proper precautions and care. The impacts can also extend to animals and plant life. Extreme heat affects individuals who work outdoors, as well as the homeless who have no access to shade or cooling. Hikers and others who participate in outdoor recreation frequently succumb to extreme heat when they run out of water or due to underlying health issues that heat exacerbates.

### **Property/Facilities/Infrastructure**

Direct impacts of extreme heat on building and structures are generally limited to long-term, maintenance related issues like material degradation and expansion/contraction related movement. Extremely hot temperatures can soften asphalt based pavements to the point of severe damage potential by heavy trucks and equipment. Improperly spaced rails can buckle due to heat expansion. Extremely hot temperatures can also ground airplanes due to the lack of air density required to generate the appropriate lift. Heat generating mechanical equipment that is cooled by air can be pushed beyond operational temperatures and possibly fail or seize if not shut-down in time. Power lines are de-rated based on the ambient air temperature, which provides cooling. High temperatures and calm conditions can lead to overheating of power lines as well as power transformers, resulting in widespread power outages.

### **Responders**

Emergency responders are typically exposed to the same extreme heat conditions as those whom they are helping and may be impacted to a greater degree if wearing heavy materials and



protective layers/equipment such as vests and helmets. Emergency equipment failure due to overheating is also possible and can hinder response capacities.

### **Continuity of Operations/Delivery of Services**

Overall, extreme heat is not a significant threat to the state's ability to effectively function unless the extreme heat durations cause other problems such as major regional power failures. Other impacts such as airport closures or localized power failures may have a local effect, but do not significantly hinder the continued operation of state agencies, services, and responsiveness.

### **Environment/Cultural**

Periods of extended extreme heat conditions may have an environmental impact by requiring the generation of more energy to produce the cool air needed to offset the effects. Increasing incidence of extreme heat can also affect air quality as concentrations of some pollutants, including ozone, are partially dependent on temperature.

### **Economic/Financial Condition of Jurisdiction**

The potential impact on our economy due to extreme heat is generally due to increased utility costs, loss of tourism, and decreased agricultural yields. Lost businesses revenues can occur with short or long-term, extreme heat triggered power outages. Pavement repair and replacement due to thermal expansion and contraction damage can be expensive to repair. Agricultural economies can be impacted through reduced plant growth and even crop mortalities, as well as reduction in dairy production and livestock mortality.

### **Public Confidence in Jurisdiction's Governance**

Extreme heat is a normal part of our climate, and state and local communities are generally prepared to deal with needs during a period of extreme heat. Most governmental agencies participate in cooperative response programs with local non-governmental charities and organizations to address the needs of the public such as distributing water and setting up cooling stations. These efforts tend to maintain and even improve public confidence in the governance of the State and local jurisdictions.

### **Cascading/Secondary Impacts**

Extreme heat can lead to human health impacts beyond heat stroke and heat-related deaths in a variety of ways. For instance, higher, less tolerable outdoor temperatures are likely to discourage outdoor exercise and recreation, as well as the use of non-motorized transportation. This, in turn, may increase the likelihood of chronic health conditions associated with sedentary lifestyles. High temperatures may also worsen existing health conditions like heart disease and respiratory illnesses, such as asthma. Extended periods of extreme heat can dry wildland fuels, exacerbating the risk for wildfire ignitions and creating favorable burn conditions.

## RESOURCES

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Maricopa County Department of Public Health, Division of Disease Control, Office of Epidemiology and Data Services, 2016, *Heat-Associated Deaths in Maricopa County, AZ, Final Report for 2016*, <http://www.maricopa.gov/ArchiveCenter/ViewFile/Item/3084>

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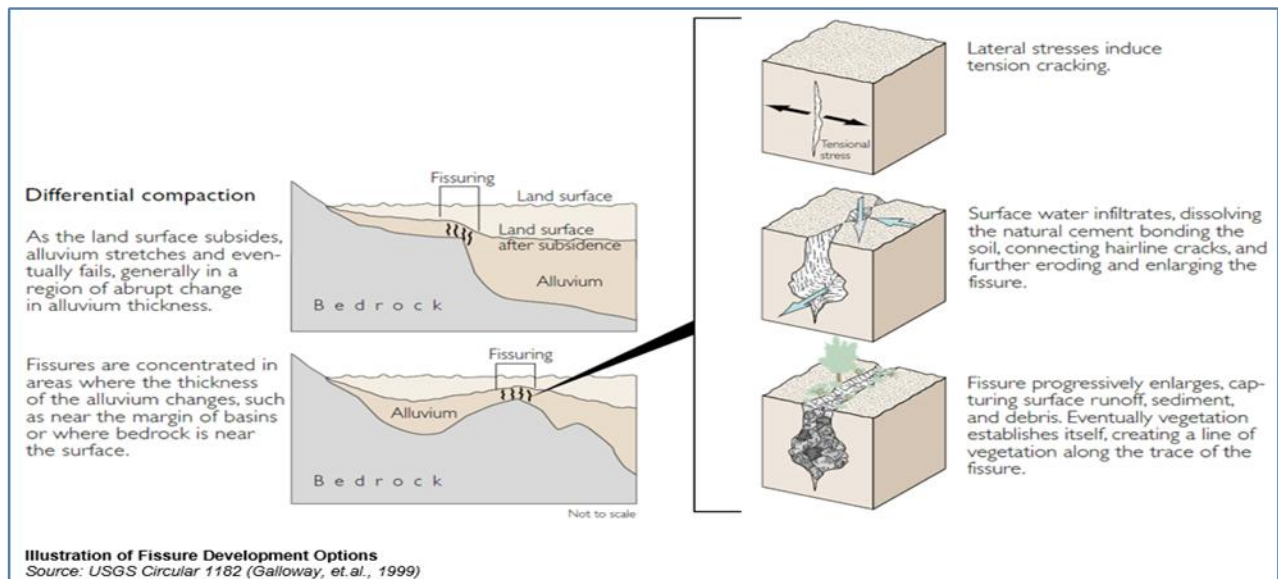
## FISSURE

Earth fissures are linear cracks, seams, or separations in the ground that extend from the groundwater table and are caused by tensional forces related to differential land subsidence. In many cases, fissures form as a direct result of subsidence caused by groundwater depletion. The surface expression of fissures can range from less than a yard to several miles long and from less than an inch to tens of feet wide. The longest fissure zone in Arizona is located in Pinal County, near Picacho, and is over eight miles long. As illustrated below, earth fissures occur at the edges of alluvium basins - usually parallel to mountain fronts, or above local bedrock subsurface pinnacles. Earth fissures generally tend to cut across natural drainage patterns, but not always. Fissures can alter flood patterns, break buried pipes and lines, cause infrastructure to collapse, provide a direct conduit to the groundwater table for contaminants, and even pose a life safety hazard for both humans and animals.



**Earth Fissure in Apache Junction**  
(Photo date 1/18/2008. Photo by Todd Shipman / Meagan Shoots)  
Source: AZGS Website at:  
<http://www.azgs.az.gov/efimagesandvideo.shtml>

**Figure 9: Fissure Formation**



## HISTORY

There are no state or federal disaster declarations for fissure occurrences for Arizona. Fissures, however, have been occurring in Arizona at least since 1927 when the first one was found near Eloy. The number of fissures has increased dramatically since the 1950s because of groundwater depletion, first because of agriculture, and later, due to exponential population growth. The risk posed by fissures is also increased as the population expands into the peripheral basin edges and mountain fronts. In 2006, Arizona enacted legislation to target the identification and public disclosure of earth fissures by tasking the AZGS to map fissures. The implied intent of this action was to mitigate the potential hazard by encouraging avoidance. Several fissure case histories documented by AZGS and others are outlined below.

### San Tan Mountains, Maricopa, and Pinal Counties

- Foothills: Fissure is undermining at least one home, and crossing several roads; dogs trapped in flash flood flowing through the fissure in 2007.
- Y-crack: Fissure crosses Hunt Hwy and San Tan Boulevard, east of Sossaman Road; present at least by 1969; catastrophically re-opened from 195th Street and Happy Road to San Tan in 2005 and again in 2007, damaging roads, corrals, fences, driveways, stranding and trapping vehicles, and killing a horse.

### Apache Junction/East Mesa, Maricopa County

- Baseline & Meridian: Fissure crosses diagonally under the intersection, fissure zone is over one-mile long.
- Ironwood and Guadalupe: Industrial facilities are built on top of several fissures in the area; mapped fissures stop immediately east of subdivision, however AZGS suspects that the fissure may extend under some existing homes<sup>1</sup>; fissures crossing power lines.

### Mesa, Maricopa County

- Loop 202 (Red Mountain Freeway): Fissure present at least since the 1970s; attempted mitigation during construction cost \$200,000.
- Sossaman Road and University Drive: Fissure runs diagonally through a subdivision along the entrance; fissure known in 1973 and subsequently backfilled.

### Picacho, Pinal County

- Picacho Peak: New 1.8-mile-long fissure identified in 2017 that is ten miles southwest of Picacho Peak State Park. The fissure is up to ten feet wide and 30 feet deep in portions.
- I-10: Arizona Department of Transportation still trying to determine effective mitigation for the fissure crossing.
- Picacho Pump Station: In 1984, a fissure crossed access road and runs nearly to canal.

### Wintersburg, Maricopa County

- Palo Verde NP: Fissure runs perpendicular to power transmission lines near Palo Verde Nuclear Generating Station; made one road impassable.

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<sup>1</sup> Personal communication from Joe Cook of AZGS.



### Scottsdale, Maricopa County

- CAP Canal: Fissure paralleling the canal opened within a few feet of the lining on the east side in 2003.
- 40th St and Cholla: Discovered in the 1980s.

### Flood retarding structures, Maricopa County

- McMicken Dam, White Tank Mountains: Dam had to be removed and replaced; cost several million dollars.
- Powerline FRS, Apache Junction: Fissure discovered within 1200 feet of the Powerline FRS embankment. Flood Control District of Maricopa County constructed an interim measure structure to keep water away from fissure and will ultimately remove Powerline FRS completely.

### Avra Valley, Pima County

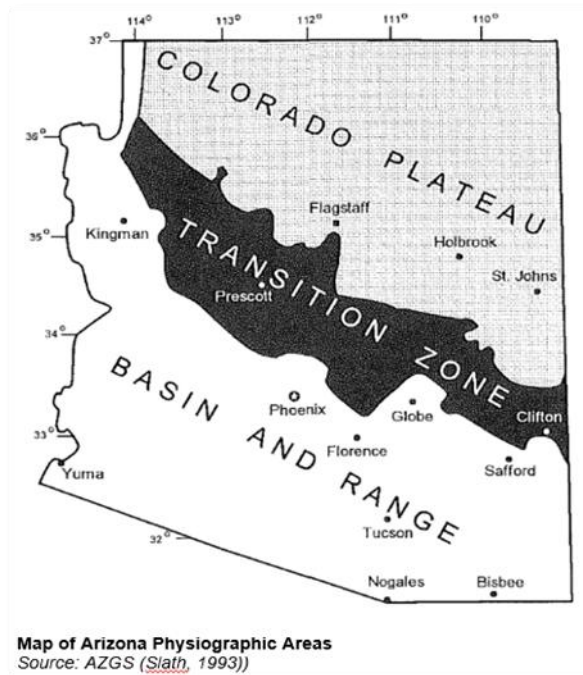
- CAP Canal: Fissure discovered in 1988 that intersected and damaged the canal just before it started conveying water. The canal section had been strengthened with reinforcing steel mats (Sandoval and Bartlett, 1991), which minimized damage to only a crack that was repaired and has not sustained further damage (Slaff, 1991).

### Near Willcox, Cochise County

- Nickels Road: In 1984, a fissure opened down one side of the road near where it crosses power transmission lines.
- Van Ness Road: Giant desiccation cracks that were initially thought to be fissures, opened up in 2011 down the middle of the road causing difficulty for local residents who may become trapped in their homes. Emergency vehicles were unable to access the area.

## PROBABILITY/EXTENT

The probability of earth fissures occurring somewhere in the state is 100%, but the probability of a fissure leading to a disaster declaration or severe statewide damage is low. The locations of increased risk for potential fissures may be highlighted to specific areas if enough information about the subsurface geology and groundwater levels is available. As long as subsidence continues (even if the groundwater levels should rise and stabilize), fissures will continue to occur. The magnitude of the fissures vary with the depth to groundwater, type of surficial material present, amount of groundwater removed, basin depth, the volume of intercepted runoff from precipitation, and human intervention. Large fissures that intersect critical infrastructure can result in severe impacts and damages.



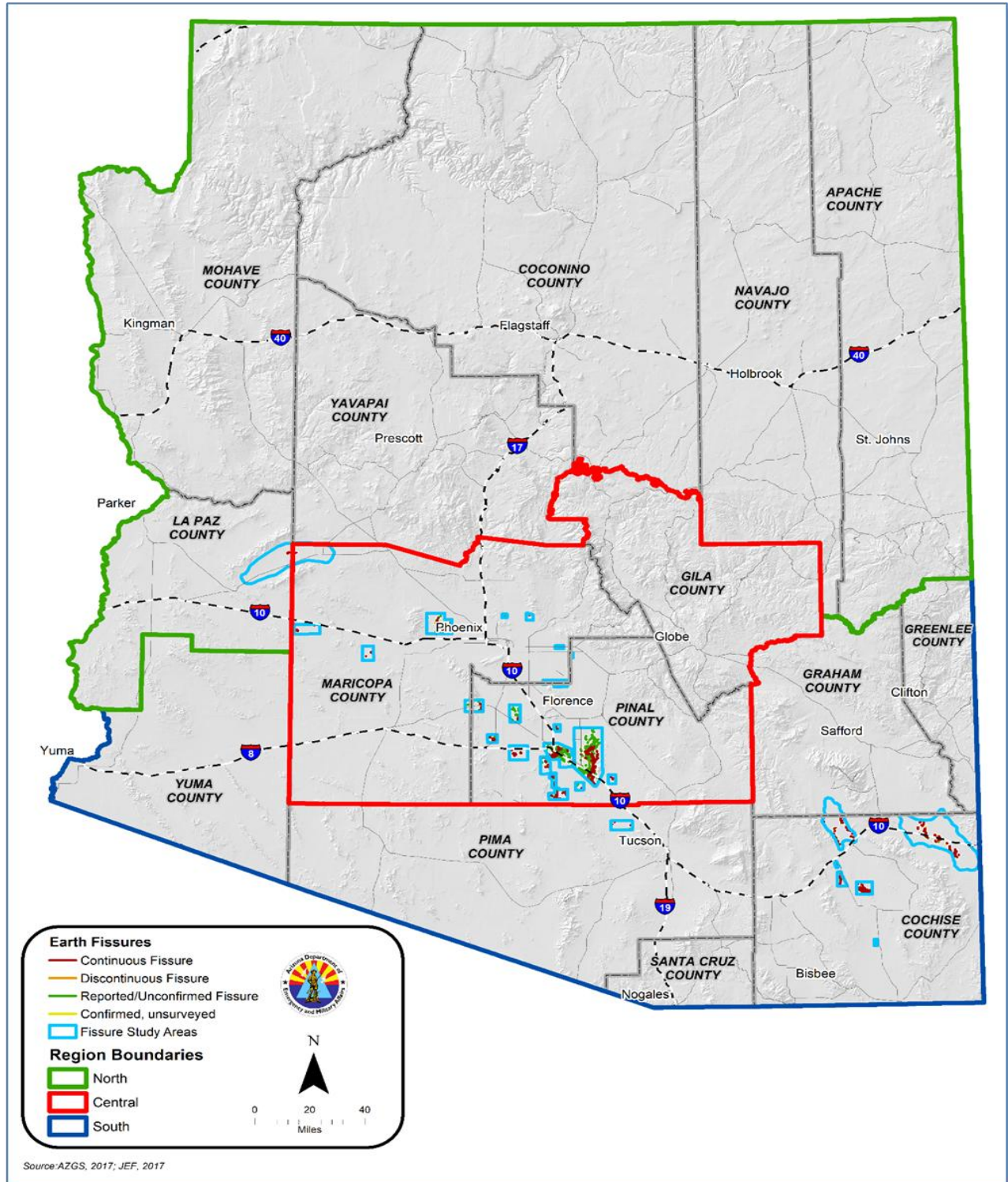
The Basin and Range Province that occupies the southern third of Arizona is the primary area susceptible to earth fissures. This area encompasses the majority of the Central and South Regions, with four counties being particularly prone to earth fissures: Cochise, Maricopa, Pima, and Pinal Counties. The Arizona Geological Survey (AZGS) has identified and mapped 26 study areas that encompass multiple identified fissure locations. Details of all areas can be accessed online at the AZGS website (see Resources section).

## **WARNING TIME**

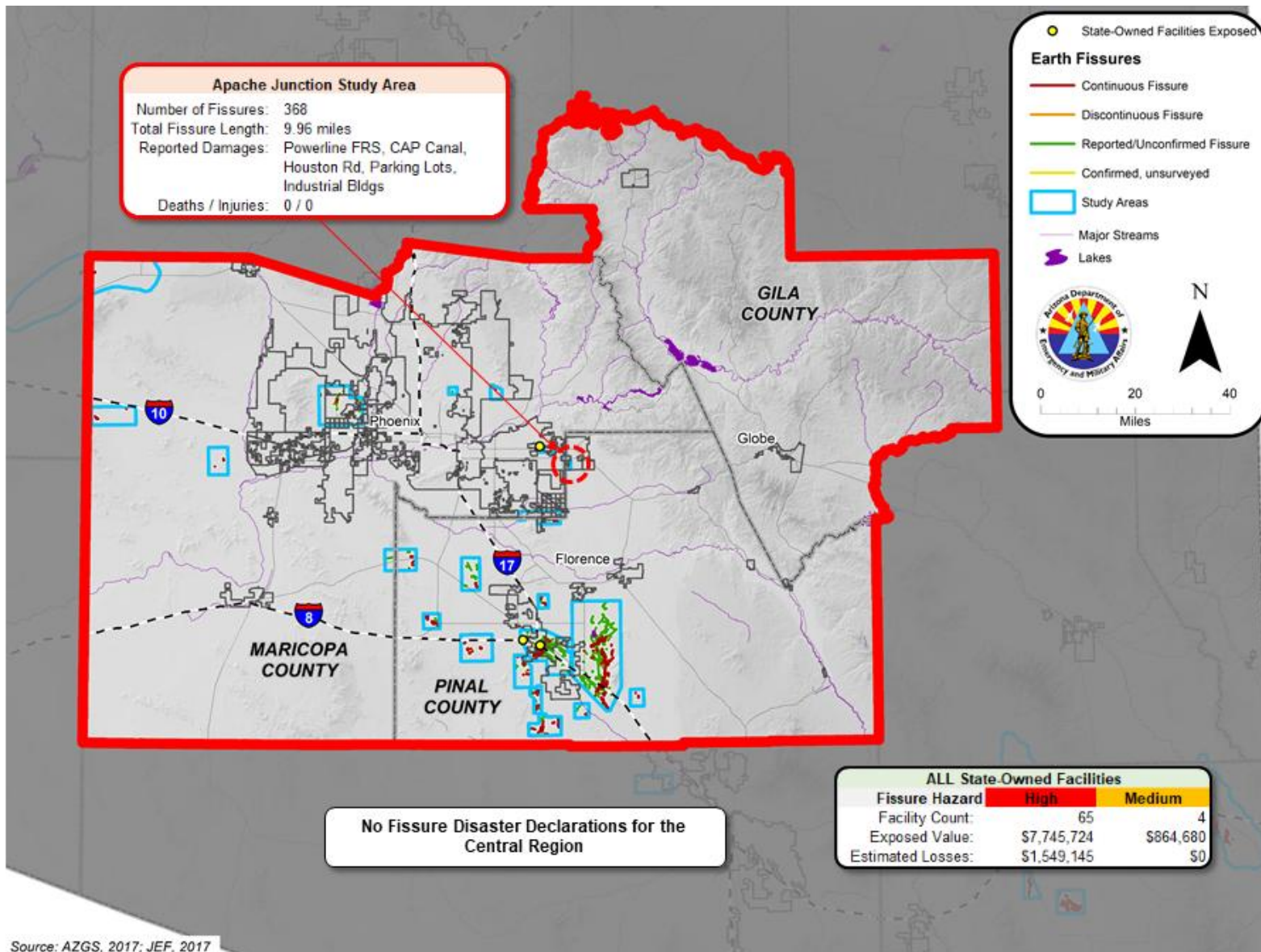
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While the process of land subsidence and subsequent fissure formation is gradual and develops over long periods of time, there is little to no warning time for a new fissure to become visible, or for an existing fissure to be activated and grow and expand. Often, the significant expansion of fissures is usually tied to a flood producing precipitation event, and therefore, tied to the warning time of those events. Alternately, the presence of previously identified fissures in an area serves as an implied warning of future new fissures or extensions/expansions of existing ones.

**Map 13: Fissure Hazard Statewide**







Map 14: Fissure Hazard for Central Region

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## FUTURE CONDITIONS

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### Climate Considerations

Since a significant number of fissures impacting Arizona are primarily the result of subsidence caused by groundwater depletion, climate change factors that influence the increased use of groundwater and recharge of the groundwater, will directly impact the fissure risk. As noted in other sections of this Plan, the projected long-term worsening or intensifying of drought periods through warming trends and precipitation influences may also have the effect of increasing the number and location of fissures in the zones of their development. The Arizona Land Subsidence Group (2007) states: *“The problems encountered with subsidence and earth fissures in Arizona will increase as groundwater continues to be withdrawn at unsustainable levels. More damage to structures and infrastructure can be expected with ever increasing economic losses, and, more importantly, a burgeoning threat to human health and safety, too.”*

### Changes in Development

Development continues to grow in areas that are subjected to the risks of fissure formation as old agricultural lands are converted to residential housing units which can increase the probability of an event. Increased water demand from new developments, combined with limited surface-water supplies, induce increased groundwater pumping that exacerbates fissure formation conditions.

#### North Region

Except for a small portion of La Paz County, most of the North Region has very low to no risk from fissures. The mapped area in La Paz County is not anticipated to develop any time soon. Development changes in other areas of the North Region are not expected to be impacted by fissure risk

#### Central Region

Development of the Phoenix Metropolitan perimeter communities (both the west and east valleys), and San Tan Valley, are expected to continue and will likely intersect with areas of known fissure hazards. Expansion of development in the Casa Grande, Eloy, and Picacho areas is expected to be limited, but may intersect areas of significant fissure activity.

#### South Region

The primary areas of identified fissure activity are located in the Avra Valley area near Marana in Pima County and northern Cochise County surrounding Willcox. Marana expects moderate growth over the next five years, but is not expected to push into the fissure areas. Very limited growth of the Willcox area is anticipated, but may intersect with the identified fissure zones.

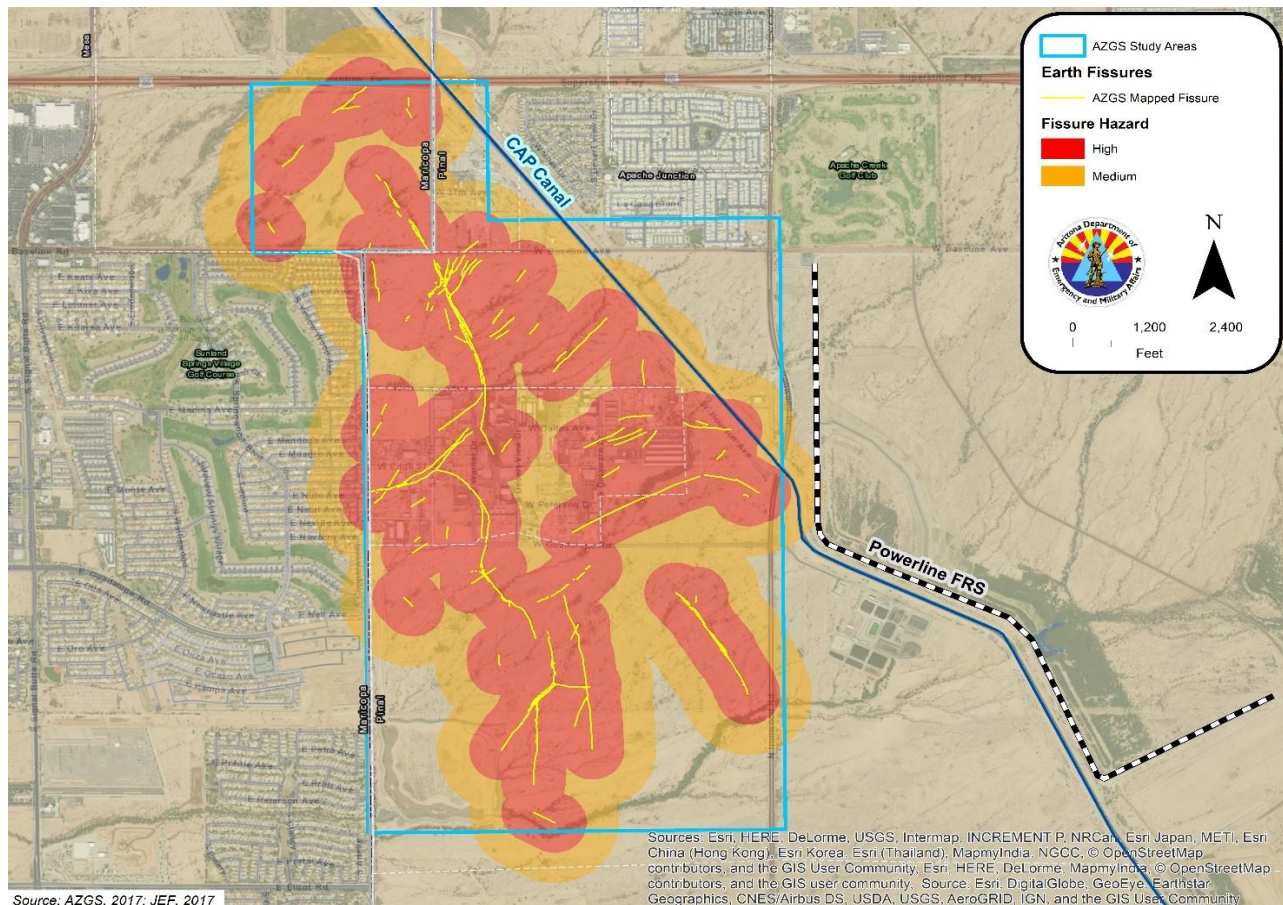


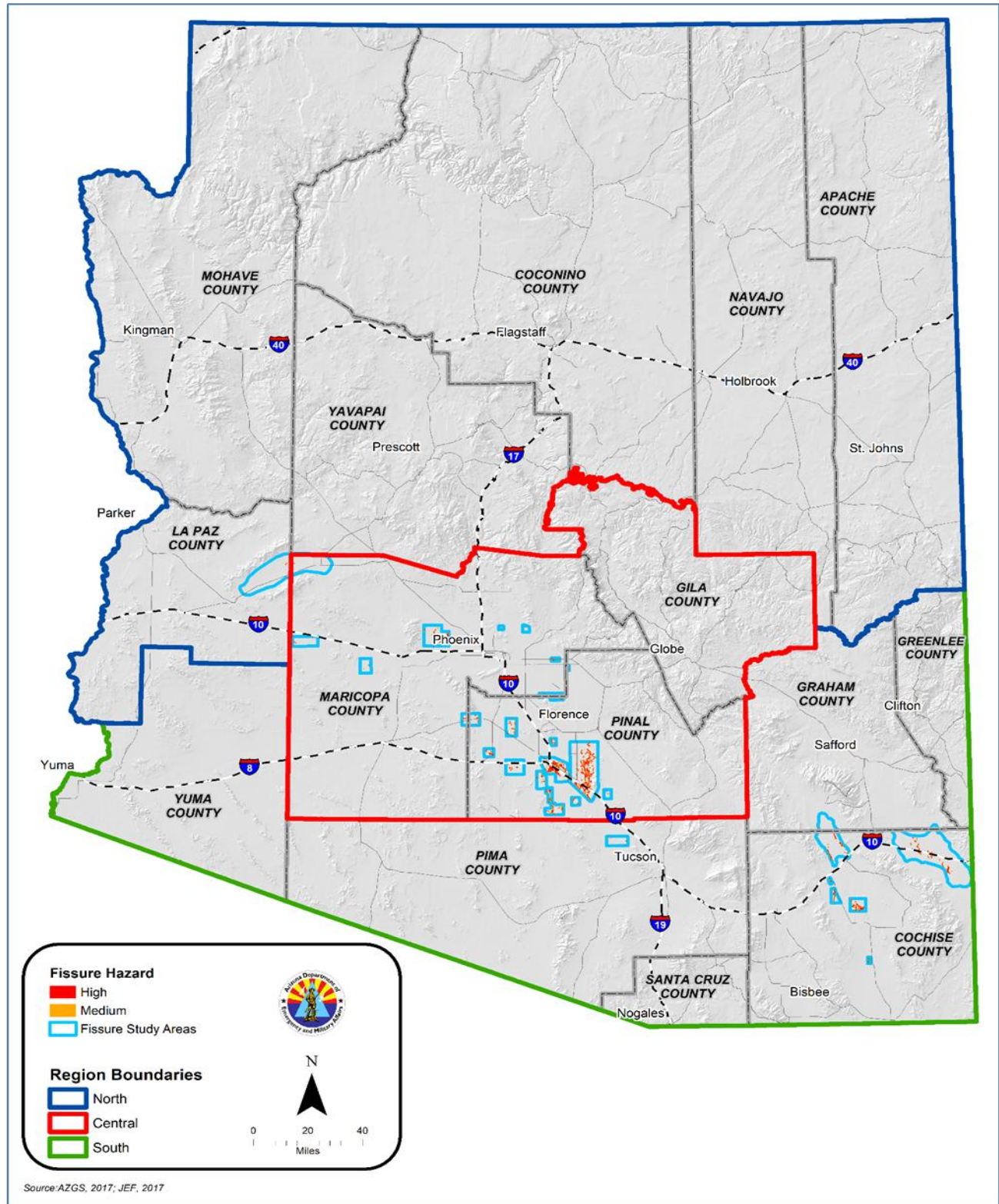
## VULNERABILITY ASSESSMENT

For the purpose of this vulnerability assessment, the Planning Team chose to estimate high and medium fissure hazard areas by creating polygons that represent a zero to 500-foot buffer and a 500-foot to 1,000-foot buffer, respectively, along all of the AZGS mapped fissure lineaments. As an example, Map 15 illustrates the results of the buffering process for fissures identified in the Apache Junction Study Area. The estimation of potential exposure to the identified high and medium fissure hazard zones was accomplished using GIS tools to intersect the human and state-owned critical facilities and infrastructure (CFI) data with the fissure hazard limits. No standard loss to exposure ratio for structures exposed or impacted by fissures is available. Instead, the Planning Team chose to estimate losses to state-owned facilities using a subjective loss to exposure ratio of 20% of the replacement value for structures located in the high-hazard zones. No losses estimates are made for assets located in the medium fissure hazard areas. Exposure estimates of the various population sectors to high and medium fissure hazards are also made.

There are only four counties (Cochise, Graham, Maricopa, and Pinal) that included fissure as a significant hazard in their local county risk assessments.

**Map 15: Fissure Hazard Areas, Apache Junction Study Area**





**Map 16: Fissure Vulnerability Statewide**



## North Region

The North Region is the least vulnerable region of the state, primarily due to the lack of identified fissures and assets at risk.

### State-Owned CFI Exposure and Loss Estimates

None of the state-owned CFI are located within a high or medium hazard area and no losses are estimated. The fissures identified in eastern La Paz County are remote and not anticipated as posing a threat to Hwy 60, which is the nearest ADOT maintained road.

### Vulnerable Population Groups

None of the 2015 estimated total North Region population of 772,157 people are exposed to either a high or medium fissure hazard. This extends to all of the sub-population groups of under 18-years of age, older than 65, poverty level, and LEP.

### Local Jurisdiction Vulnerability

None of the local jurisdictions in the North Region included fissure in their risk assessments. Accordingly, there are no estimated quantitative fissure related losses for locally identified critical and non-critical facilities.

### Specific Areas of Concern

There are currently no special areas of concern for the North Region. Fissure development in McMullen Study Area will continue by the AZGS, but the area is unpopulated and not anticipated to threaten any of the nearest state-owned or maintained facilities.

## Central Region

The Central Region is the most-vulnerable region in the state, largely due to the number and density of identified active fissure areas, significant population and infrastructure within some areas, and exposure of population and state-owned facilities.

### State-Owned CFI Exposure and Loss Estimates

A total of eight state-owned CFI, or 100% of the statewide exposure, are located within a high or medium hazard area. The exposed facilities represent total replacement values of \$3.33 million, with an estimated \$864,680 in potential losses.

Additional state-owned facilities vulnerable to fissures are the ADOT operated and maintained freeways, highways and state routes that pass through known fissure hazard areas. For example, the reaches of I-10 and I-8 passing through the Picacho Peak and Friendly Corner, and Toltec Buttes Study Areas have historically been impacted by fissures that pass under the freeways (Slaff, 1993). Future damages are dependent on activation of the fissures (existing or new), and based on past history, could be tens to hundreds of thousands of dollars. To-date, only short-term mitigation has been possible and additional repair and mitigation expenses are anticipated to continue into the future.

### Vulnerable Population Groups

The 2015 estimated total population for the Central Region is 4,604,414 people. Approximately 0.40 % of the total population, or 18,250 persons, are located within the high and medium fissure hazard areas.

On average, approximately 6.7% of the Central Region population is estimated to have a Limited English Proficiency (LEP). Assuming the percentage is equally applied across the whole region's population, roughly 515 (6.7% of 7,687) LEP persons are estimated to be located within the high hazard area and 1,001 LEP persons (6.7% of 10,563) are estimated to be located within the medium hazard areas.

### Local Jurisdiction Vulnerability

Maricopa and Pinal Counties included fissure in their risk assessments and used a similar buffering approach to define fissure hazard zones. Between the two plans, a total of 21 assets with a total replacement value of \$16.2 million have been identified as located within a high hazard area. A total loss to local CFI was estimated at \$3.2 million.

### Specific Areas of Concern

When activated, fissures can open rapidly and even suddenly depending on their formation, threatening life and property. In the Chandler Heights Study Area, a sudden collapse of a cavity formed on a fissure caused the death of a horse. In the same area, a motorist drove into a crevice formed overnight along an activated fissure causing damage and injury. Extra attention to developments proposed for areas with known fissure zones is critical to effective mitigation.

## South Region

The South Region is the second-most vulnerable region in the state, largely due to the scattered presence of identified fissures in Cochise, Graham, and Pima Counties and a limited history of damages. Most of the fissure hazard areas are in remote rural or undeveloped areas outside of the region's population centers.

### State-Owned CFI Exposure and Loss Estimates

None of the state-owned CFI are located within a high or medium hazard area and no losses are estimated. A few of the Cochise County fissures are located near I-10 and Hwy 191, and may upon activation, cause damage to those road segments.

### Vulnerable Population Groups

The 2015 estimated total population for the South Region is 1,458,367 people. Approximately 0.01 % of the total population, or 152 persons, are located within the high and medium fissure hazard areas. Of those, 36 persons are under the age of 18, 26 are over the age of 65, and 15 are living at or below poverty level.

On average, approximately 12.7% of the South Region population is estimated to have a Limited English Proficiency (LEP). Assuming the percentage is equally applied across the whole region's population, roughly eight and 11 LEP persons (12.7% of 65 and 87) are estimated to be located within the high and medium fissure hazard areas.

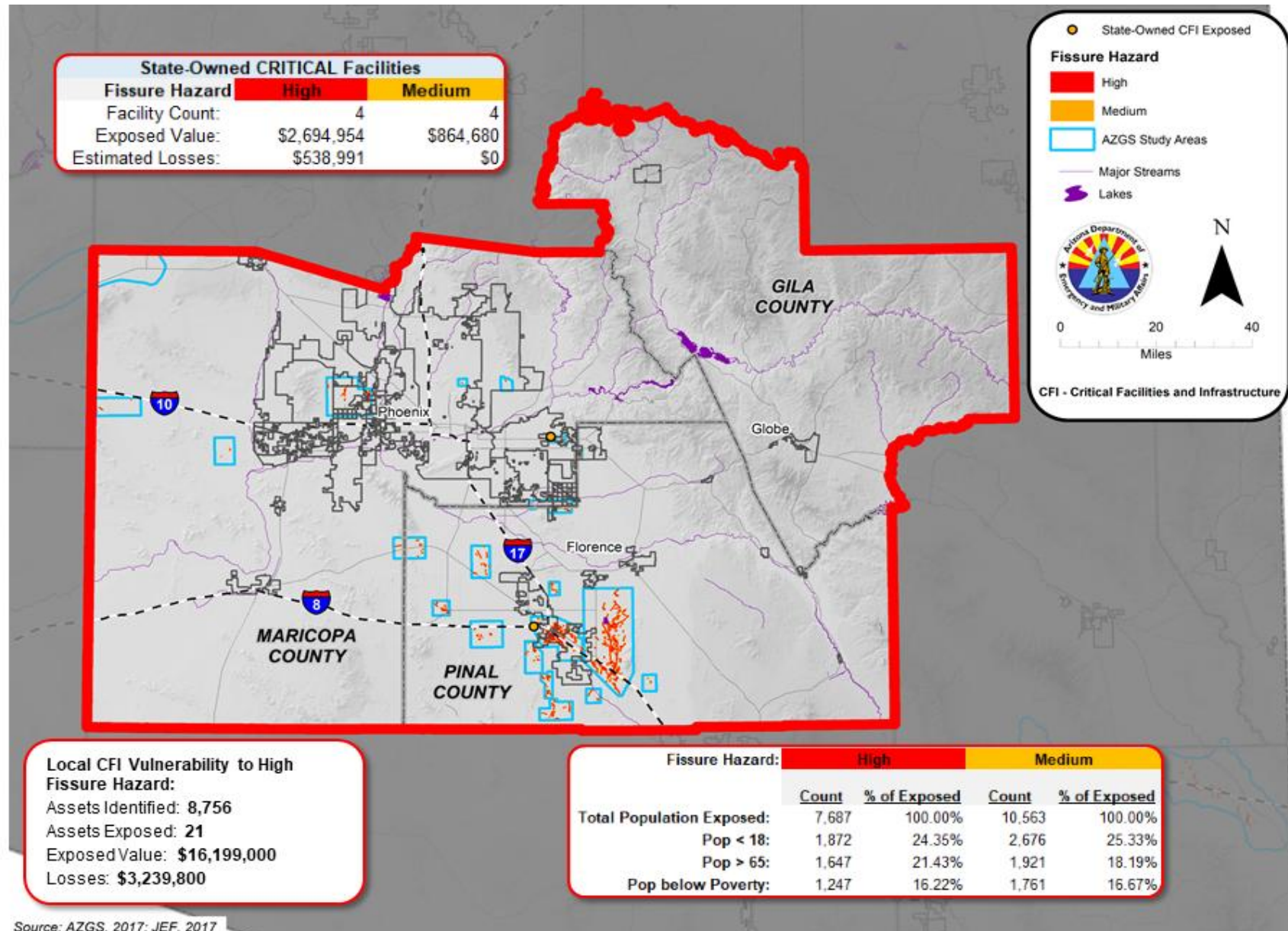
### Local Jurisdiction Vulnerability

Cochise County is the only jurisdiction in the region to include fissure in their risk assessment, and no mention is given to local CFI exposure or losses. The Cochise County plan noted that a total of 287 parcels of land in the unincorporated county were impacted by fissures. None of the other South Region counties included fissure in their risk assessments.

### Specific Areas of Concern

Similar to the Central Region, monitoring of development in or near areas of known fissure activity is crucial to effective mitigation. Most of the areas in the South Region are remote, but expansion of growth around Willcox may increase exposure in those areas.



**Map 17: Fissure Vulnerability for Central Region**

## **POTENTIAL CONSEQUENCES AND IMPACTS**

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### **Public**

There are multiple direct and indirect impacts to public health that are attributable to earth fissures. Fissures may form or expand unexpectedly under buildings, on properties, in roads, flood control structures, canals, and dams. Failure of any of these could result in catastrophic losses. Since fissures are essentially direct links to the groundwater table, contamination of private and public wells could result from pollutants entering the groundwater through the fissure. Damages to buildings impacted by fissure can lead to condemnation of the structure, forcing displacement of the owners for months or even permanently.

### **Property/Facilities/Infrastructure**

Activation of a fissure intersecting property, facilities and infrastructure can result in significant damage and even catastrophic failure. Foundation failure for buildings and structures can result from differential settling caused by removal of soil support at fissure trenches. Breaches to canals, leveed flood control channels, and dams can result via piping failures that originate at a fissure. Breakage of buried pipelines due to exposure, differential settling, or lateral tension from fissure trench widening can occur. Damage to transportation corridors (roadways and railroads) can occur through cracking of drive surfaces, collapse of subterranean trenches, and rail separation or misalignment.

### **Responders**

Fissure threat to responders is generally limited, but can come in the form of unexpected collapse or crevice formation within a lifeline corridor travelled by emergency and response vehicles. There is also a threat of unexpected collapse of fissure trench walls for responders working an incident.

### **Continuity of Operations/Delivery of Services**

Fissures do not pose a significant threat to the state's ability to continue effectively functioning. Delivery of services to a local area may be temporarily hindered if key infrastructure is compromised or access is limited or denied, but the overall impact is considered negligible.

### **Environment/Cultural**

Fissures are detrimental to the environment in several ways. Once fissures open on the surface, they become a direct conduit for pollution to enter the groundwater table. These contaminants may include animal waste, chemicals, or other hazardous substances. Fissures also become attractive locations for people to dump trash and rubbish (e.g., used automobile tires, construction debris, mattresses, etc.). Fissures can also impact natural drainage paths by intercepting floodwater and redirecting the flows away from the historic floodplains and flooding places that previously did not have flooding impacts.

Several of the AZGS mapped fissures are located on or near tribal lands and may have the potential to impact sacred sites or other culturally valuable resources, including historic prehistoric irrigation canals.

## Economic/Financial Condition of Jurisdiction

Economic impact due to earth fissures can be a result of damaged transportation systems, buildings, sewage facilities, irrigations systems, water-storage systems, pipelines and agricultural fields, just to mention a few. Areas prone to or experiencing fissures may also be affected by decreased property value as well as increased cost of development projects caused by modifications necessary to mitigate fissure risk. These costs may directly or indirectly affect the jurisdiction in costs or tax base.

## Public Confidence in Jurisdiction's Governance

In general, the public's confidence in the state's ability to govern is not greatly affected by fissures. On a local level, proven methods for providing long-term mitigation of fissure risk beyond pure avoidance, are still unknown and can leave an affected public with an eroded confidence in their local jurisdiction's ability to address fissures in their communities.

## Cascading/Secondary Impacts

Cascading events resulting from earth fissures is broad, ranging from accelerated erosion rates which undercut foundations, roads, gas and water lines, to contamination of fresh water aquifers. The latter is the most serious of secondary events, since entire communities may be affected by the contamination. In addition, mitigation may prove difficult, expensive and could require years of pumping and filtering to purge the contaminated waters. Other impacts include:

- Harm to livestock – cattle and horses, which can stumble into fissures and find it difficult or impossible to get out.
- Accelerated erosion rates leading to head-cut erosion, top-soil removal, gully development, and permanent alteration of historic flood patterns.
- Breaches to canals, leveed flood control channels, and dams can result via piping failures that originate at a fissure location.
- Exhuming buried gas or water lines – potentially leading to broken mains leading to fires or local flooding.
- Dumping of organic and inorganic substances into fissures (tires, appliances, and sundry trash items are commonly dumped into fissures).
- Potential for direct contamination of groundwater, and the associated disruption of water delivery to homes, municipalities, and farm fields.
- Breakage of buried pipelines due to exposure, differential settling, or lateral tension can lead to loss of service, flooding from water lines, contamination from wastewater or fuel lines, and fire from leaking gas lines.



Source: Michael Carpenter, USGS (Galloway, et al., 1999)

- Damage to transportation corridors (roadways and railroads) can lead to accidents or disruption of travel due to cracking of drive surfaces, collapse of subterranean trenches, and rail separation or misalignment. For example, Slaff (1993) reported that fissure formation misaligned a section of railroad track in the Picacho Basin causing a train to derail.

## RESOURCES

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### Sources

AZ Geological Survey in partnership with the AZ Dept of Emergency and Military Affairs, Hazards Viewer, <http://data.azgs.az.gov/hazard-viewer/>

AZ Geologic Survey, Arizona's Earth Fissure Center, <http://www.azgs.az.gov/EFC.shtml>

Arizona Land Subsidence Group, <http://azlandsubsidence.org/>

### References

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Gelt, J., 1992, *Land Subsidence, Earth fissures change Arizona's Landscape*. University of Arizona's Water Resources Research Center, Arroyo, Vol. 6, No. 2. <https://wrrc.arizona.edu/publications/arroyo-newsletter/land-subsidence-earth-fissures-change-arizonas-landscape>

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Slaff, Steven, 1991, *Earth -Fissure Activity Near Brady and Picacho Pumping Plants, Tucson Aqueduct, Central Arizona Project, Pinal County, Arizona*. AZ Geological Survey Open-File Report 91-1, prepared for the US Bureau of Reclamation.

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## FLOODING

Flooding is the most common and most expensive hazard in Arizona. Since February 1966, the state has experienced 132 flooding incidents of sufficient magnitude to prompt a Presidential or Gubernatorial disaster declaration, which is more than any other hazard category to-date.

**Precipitation Event Types** – Three seasonal atmospheric conditions tend to trigger significant flood events in Arizona:

### Tropical Storm Remnants

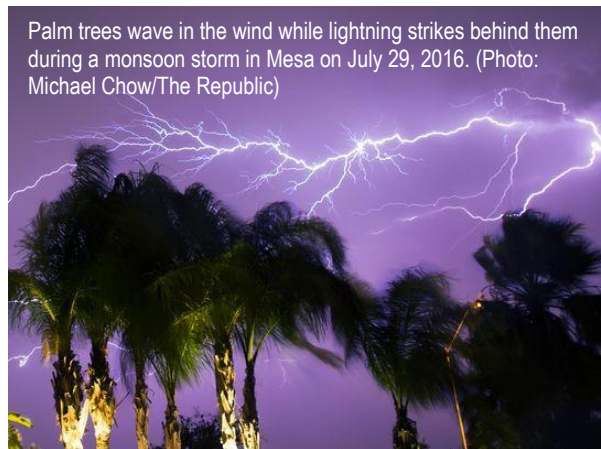
Historically, the most regionally severe flooding occurs when remnants of hurricanes and tropical storms enter the state. These events infrequently occur (i.e. approximately every ten years), mostly in early autumn, and can bring several days of prolonged, intense precipitation events covering large regions that can cause severe flooding. In general, the flood hazard imposed by tropical storm remnants tends to degrade with northern movement through the state. The Southern Region and lower Central Region are usually impacted the most.

### Winter Rains

Winter brings the threat of low intensity, long duration rains that cover large areas and cause extensive flooding and erosion, particularly when combined with snowmelt that increases runoff after rain falls on significant snowpack. The El Nino climate phenomenon can influence winter storms and cause severe flooding. Winter rains tend to impact the Northern Region northernmost portions of Central and Southern Regions.

### Summer Monsoons

In mid to late summer monsoon winds bring humid subtropical air into the state. Solar heating triggers afternoon thunderstorms that can be devastating. Flash flooding may occur as a result of local, intense rainfall in a short period (usually six hours). Many Arizona communities get half of their annual rainfall during the summer monsoon from June 15 to September 30. Summer monsoons impact areas statewide, but tend to be strongest in the Central and Southern Regions.



Palm trees wave in the wind while lightning strikes behind them during a monsoon storm in Mesa on July 29, 2016. (Photo: Michael Chow/The Republic)



## **Flood Types**

Flooding can occur in several different ways and is generally characterized into the following types:

### **Riverine**

The most common type of flooding occurs along well defined watercourses such as rivers or desert washes. Many of the watercourses within the state are ephemeral and typically remain dry until significant rain causes flooding.

### **Shallow Sheet Flow**

Flooding that occurs in areas that are fairly flat with no definable washes or low-flow areas of significance. The flooding occurs as a shallow sheet of water that can be several feet deep. Depending on the slope of the land, there can also be ponding, and the sheet flow can be slow or move fast enough to cause erosion.

### **Distributary flow**

Flooding in relatively flat areas where the watercourse divides and braids into smaller channels or branches that are subject to either further erosion and expansion, or plugging with debris and sediment.

### **Alluvial fans**

In the arid southwest, active alluvial fans can develop at locations where steep mountain washes abruptly transition to flatter alluvial piedmonts located at the base of the mountain. During flood events, the steep washes carry heavy sediment loads that deposit in a fan-shape, with one or more primary flow paths of concentrated flooding that can change location across the fan face with any given flood event. The point of slope change at the upper-most portion of the fan is known as the fan apex. It is noted that alluvial fans and distributary flow areas are similar; however, alluvial fans are significantly more active and volatile in moving the primary channel(s) and creating new flow paths.

## **Post-Fire Flooding**

Normally, vegetation absorbs and attenuates the impact of rainfall, which reduces runoff. Wildfires leave the watershed charred, barren, and can physically alter the ground's ability to absorb water, creating conditions ripe for flash flooding and mudflow. Flood risk remains significantly higher until vegetation is restored—up to five years after a wildfire. Flooding after a wildfire is often significantly more severe, as debris and ash left from the fire can combine with eroded soil and sediment to form mudflows. The combined increase of floodwaters and mudflows can cause significant damage to areas downstream of the burned watershed.

## **HISTORY**

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The following are a few examples of significant floods that have occurred in the state:

- July 15, 2017 – Ten family members died after a flash flood swept them downstream. While swimming in the Cold Springs swimming hole, rain fell eight miles upstream of them along the Ellison Creek watershed. This area is within the burn scar of the 7,198-

acre Highline fire from June of 2017. The flash flood sent a six-foot-high and 40-foot-wide wall of water laden with debris, tumbling downstream.

- October 8, 2016 – Safford in Graham County experienced two inches of rain and six inches of hail. This caused damage to homes and cars and a collapse of 12<sup>th</sup> Avenue. The state declared a disaster on October 19<sup>th</sup>.
- September 14, 2015 – Flash floods in the community of Hilldale, Utah and Colorado City, in Mohave County, caused the deaths of 12 people who were swept away in their vehicles. The flooding spilled into an overbank area of the main watercourse and flanked the unsuspecting parked vehicles, carrying them downstream.

- September 8, 2014 – Remnants of hurricane Norbert produced storms with rainfall more than two inches per hour. Major flooding caused damage in La Paz, Maricopa, Mohave, and Pinal Counties. Over 125 homes in Mesa near Val Vista and US 60 were in danger of flooding. A fatality was reported in the Oracle Road area after a 76-year-old woman was swept away when her car was caught in the flood waters. \$2,608,829 from the Governor's Emergency Fund was utilized to help with over 150 disaster recovery projects.



- October 3-5, 2010. The Havasupai Reservation experienced severe flooding in Cataract Creek, and three major surges of water arrived in Supai Canyon. The flood caused damages and destruction of trails, bridges, homes, community facilities, campgrounds and recreation areas in Supai Canyon. Tourists were evacuated and several animals were lost. The Havasupai Tribal Council officially declared a State of Disaster on the Havasupai Reservation and closed Supai Village and the surrounding areas to visitors indefinitely until recovery, repair, rehabilitation and mitigation work is completed.
- July 20-August 7, 2010 - Following the Schultz Fire burning more than 15,000 acres of US Forest Service land, the soil became hydrophobic. This soil condition, paired with repeated heavy rains resulted in substantial flooding downslope from the burn area. This event led to presidential declaration, and the expenditure of more than \$7 million dollars between the state and federal resources.
- January 18-22, 2010 - Severe winter weather hit the northern part of the state and heavy rains fell in the lower elevations causing significant flooding. In February, the a state emergency was declared and in March, the President declared a major disaster for Arizona. Preliminary damage assessment reports indicated that 51 residences were destroyed, 64 sustained major damage and 474 more were affected or received minor damage. The total individual assistance cost was estimated at \$3.6 million. Public

assistance damages were primarily related to roads and bridges throughout the impacted areas with over \$11.4 million in damages estimated.

- Summer 2008 - Heavy monsoon rains in the border area around Nogales caused severe flooding, two fatalities, and millions of dollars of damage; a State of Emergency was declared in Nogales for the second year in a row. Floodwaters damaged a concrete-lined drainage channel that protects a raw sewage pipe. The sewer line, buried beneath the channel, carries sewage from Nogales, Sonora to a wastewater treatment plant north of Nogales USA. It is predicted that a break in the sewer line would release contaminated water into the Santa Cruz River, which flows north toward Tucson (DEMA, 2009).
- Summer 2006 - Record rainfall in eastern Pima County triggered unprecedented flooding, slope failure, and debris flows in Tucson and the nearby Santa Catalina Mountains, which culminated with a four-day rainfall event on July 31 that the National Weather Service estimated as a 1,000-year event in the mountains. Streamflow on the Rillito River through Tucson exceeded the 500-year event. The USGS documented 435 slope failures and debris flow events in the southern Santa Catalina Mountains, which they termed “an extreme event,” (Pima Co Regional Flood Control District, 2008).



## **NATIONAL FLOOD INSURANCE PROGRAM (NFIP)**

As of July 31, 2017, 32,775 homeowners in Arizona had purchased flood insurance through the NFIP program. It is important to note that flood insurance is mandatory for a building constructed in a federal floodplain that has a federally-backed mortgage. During the period of January 1, 1978, through July 31, 2017, there were 4,619 losses and approximately \$47.5 million in payments reported for Arizona’s NFIP communities. FEMA records indicate there is one Severe Repetitive Loss (SRL) and nine Repetitive Loss (RL) properties identified in Arizona. There are multiple sources with varying standards for what constitutes SRL and RL properties. This Plan acknowledges the FEMA identified SRL and RL properties in accordance with the Flood Mitigation Assistance (FMA) grant requirements.

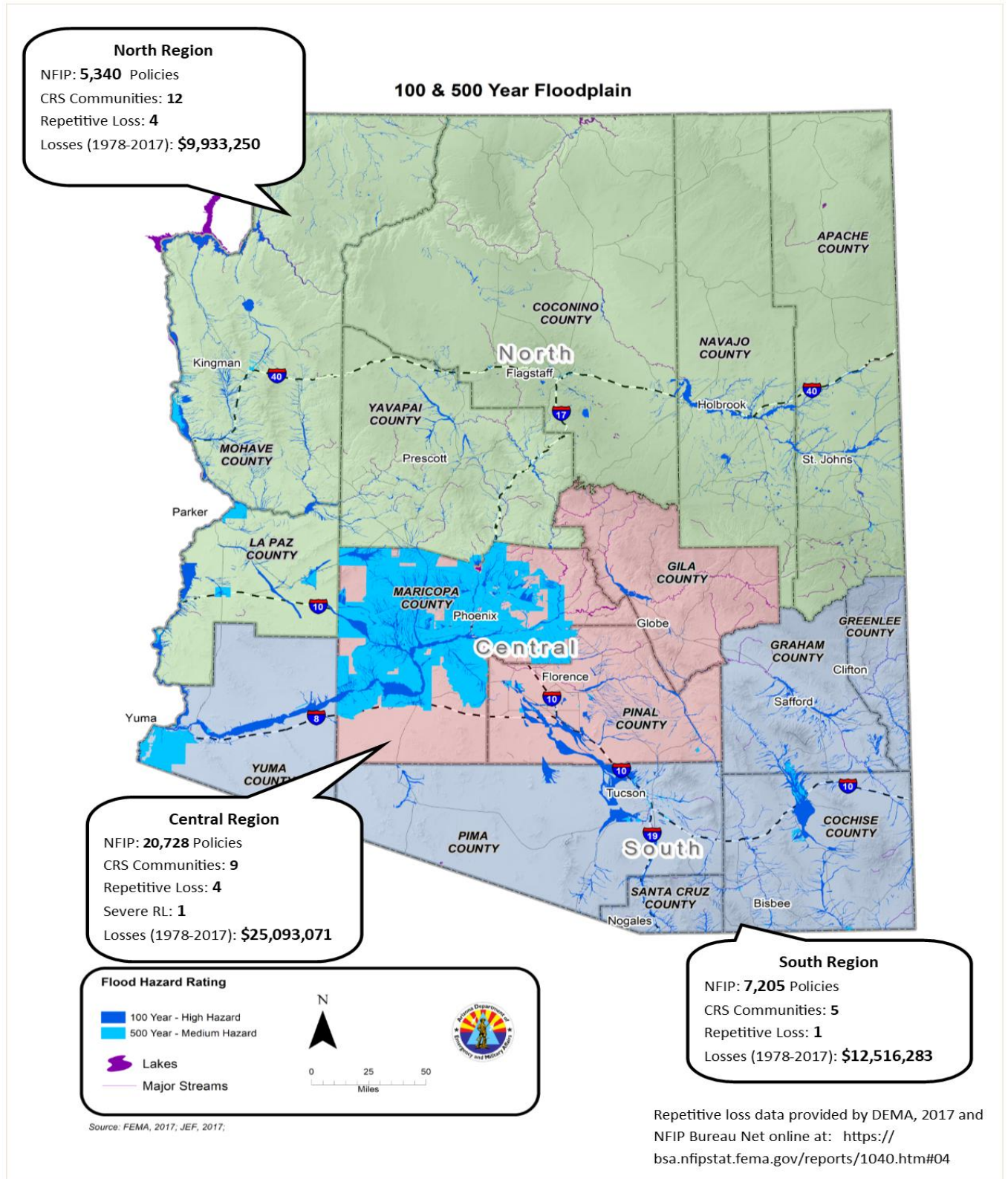
ADWR’s floodplain management program is partially funded by FEMA’s Community Assistance Program (CAP). One of the main objectives of the CAP is to assure that jurisdictions adopt and enforce floodplain management regulations in accordance with requirements of the NFIP and the Arizona Revised Statutes (ARS). Through this program, Community Assistance Visits (CAVs) are made to the state’s NFIP participating communities. It is the goal of ADWR to visit communities periodically to provide updates on state and federal floodplain management program changes, provide technical and programmatic assistance and verify that development in flood-prone areas is compliant with local floodplain management regulations. The Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages a community’s floodplain management activities that exceed the minimum NFIP requirements.

Flood insurance premium rates are discounted to reflect the reduced flood risk resulting from community measures that meet the goals of the CRS program.

The map below details the number of NFIP policies, loss claims made by flood insurance policyholders, repetitive and severe repetitive loss properties, and the number of CRS communities for each of the DEMA field operations regions.



**Map 18: NFIP Status Statewide**





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## PROBABILITY/EXTENT

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The probability of floods occurring in Arizona is very high. The extent of the flood hazard can vary greatly and is influenced by many factors including the volume and intensity of precipitation, geography, land-use characteristics. One of the most widely adopted design and regulatory standards for flooding in Arizona is an event of a certain magnitude that has a 1% probability of occurring in any given year, or the 1% annual flood. The 1% annual flood is the standard formally adopted by FEMA for regulatory use and is often referred to with the recurrence interval moniker of “100-year flood.” The reality is that a community could experience multiple 1% annual flood events (100-year floods) in a given year.

For this Plan, the inundation limits of the 1% annual flood is designated as the ‘high’ risk area, and the 0.2% flood inundation limits is labeled ‘medium’. The geospatial limits for the high and medium flood hazard areas are derived from FEMA’s most current National Flood Hazard Layer data, and are presented by region on the profile and vulnerability maps in this section.

Another measure of the likelihood of a damaging flood occurring in the state based on historic incidents can be made using the average number of flood related disasters declared by the state per year. Records dating back to 1966 indicate that there have been a total of 78 state declared disasters related to flooding, with the last state declaration occurring in August 2017. This equates to a statewide average of 1.5 flood related declarations per year.

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## WARNING TIME

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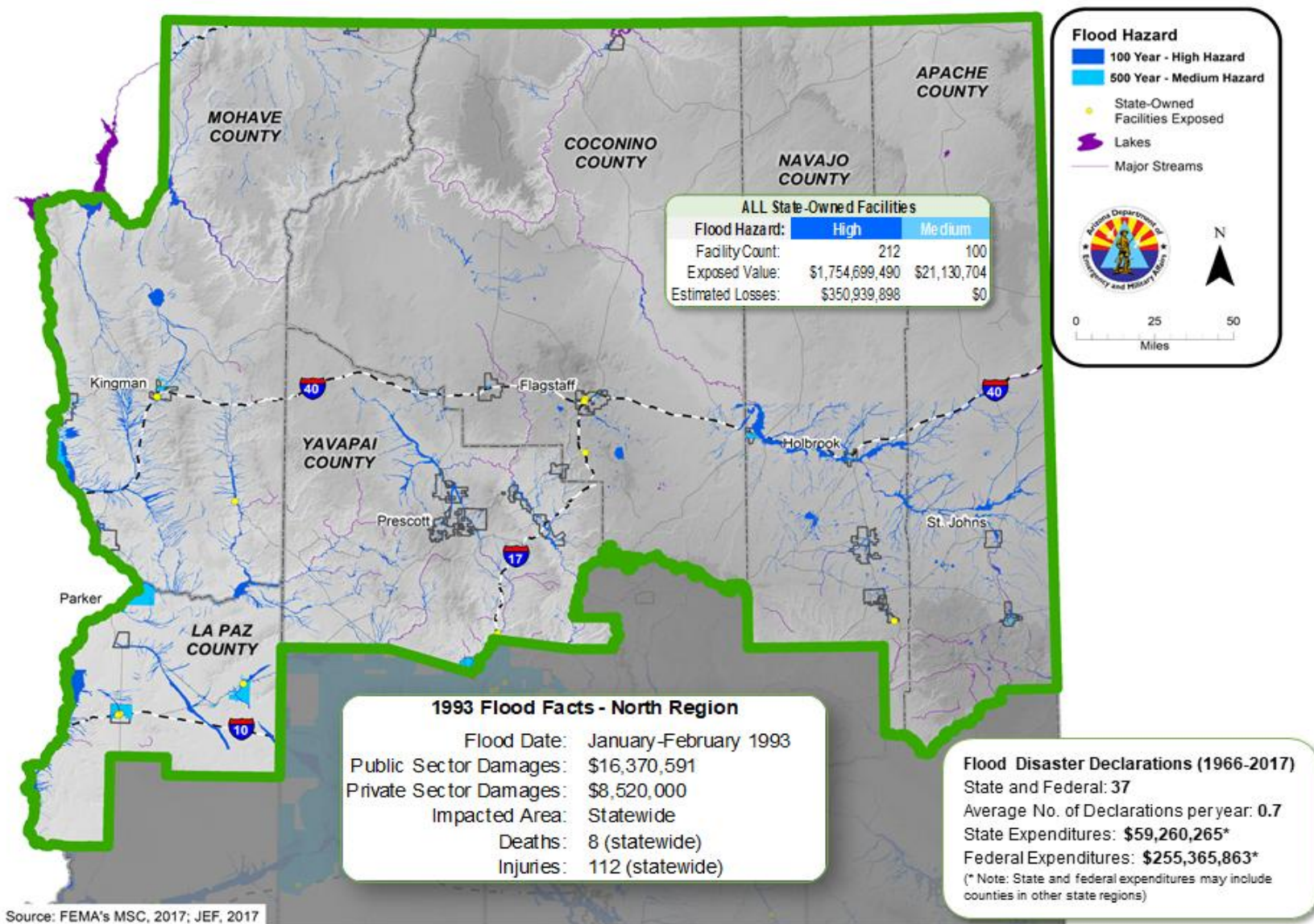
Warning time for flood related events is composed of the time needed to assess and issue a meteorological warning for a probable precipitation event, and the time from initiation of precipitation to time that peak flooding. For Arizona, those times will vary depending on the type of precipitation event and the size of the watercourse and tributary watershed.

### Summer Monsoons

Typical monsoon thunderstorms develop rapidly and are relatively small in areal extent with short duration, high intensity bursts of rainfall that result in swiftly moving flash floods. The full warning times for monsoon events are usually less than a couple of hours and flood peak arrival times can be measured in minutes for small watersheds. Many of the fatalities associated with flood events within the state are due to thunderstorms that caused flash floods that caught people unaware.

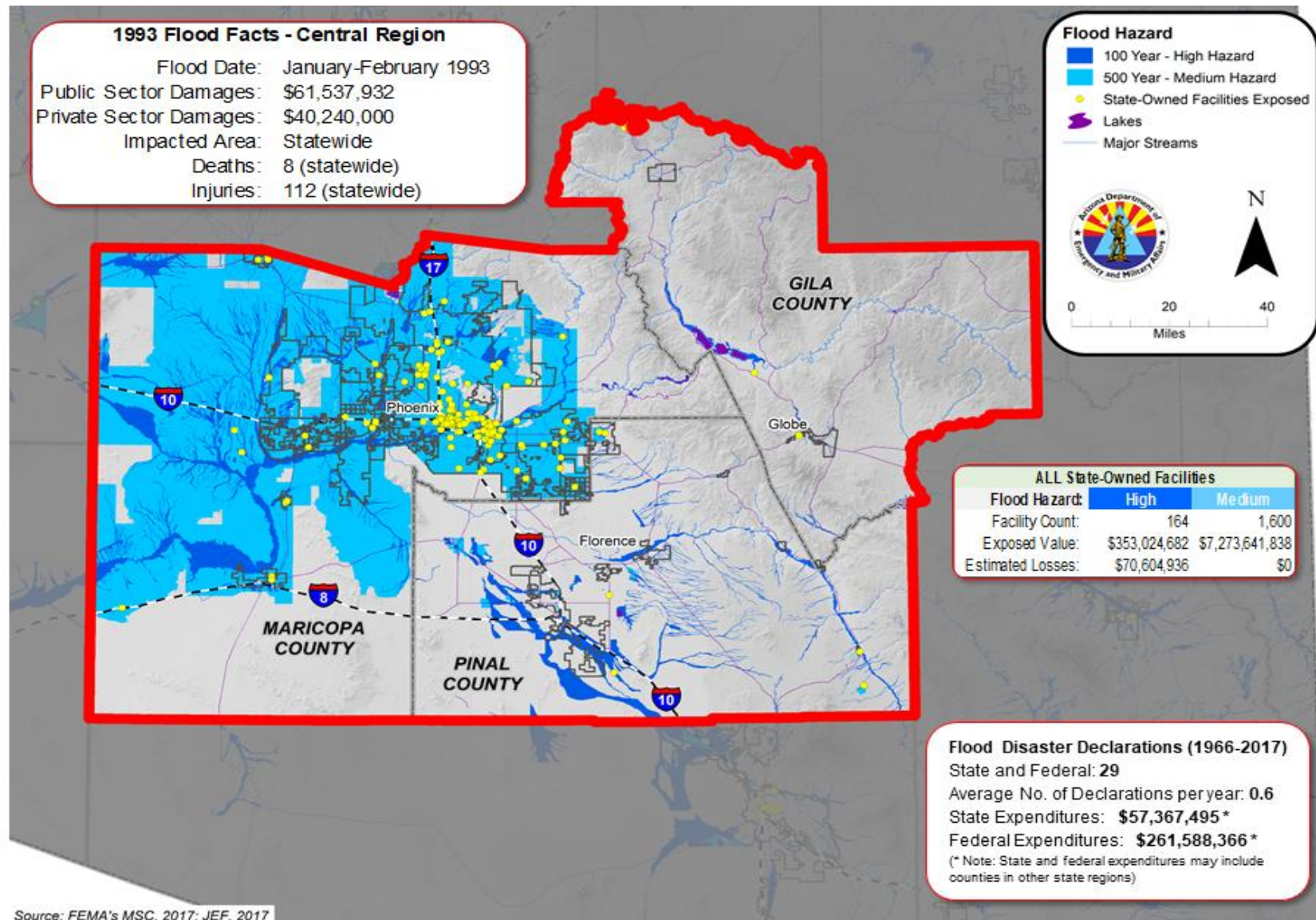
### Tropical Storm Remnants

Tropical storms moving into Arizona typically have more advanced meteorological notice and tracking. Rainfall areal extents and durations are typically larger and longer than monsoon storms, but intensities can still generate fairly rapid peak flows. Full warning times for tropical storm remnants are usually greater than six hours, with flood peak arrival times in a couple of hours depending on the watercourse and watershed size.

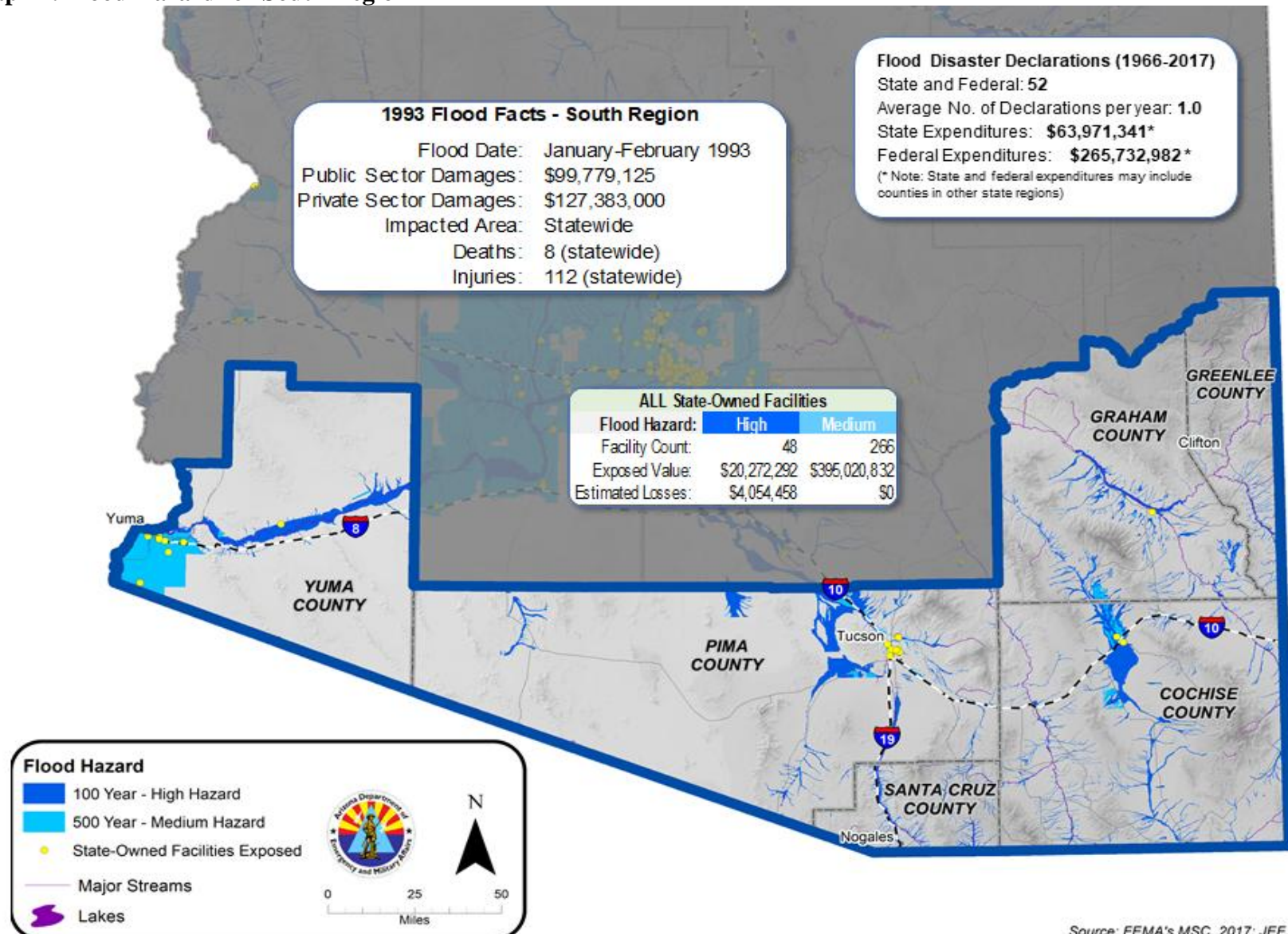


Map 19: Flood Hazard for North Region





Map 20: Flood Hazard for Central Region

**Map 21: Flood Hazard for South Region**

## **Winter Rains**

General winter storms have longer duration, low intensity rainfall that covers large areas of the state and produces runoff that gradually accumulates to peaks flood stages. Winter storms moving into Arizona typically have more advanced meteorological notice and tracking. Full warning times generally exceed 12 hours, with flood peak arrival times in several hours.

## **FUTURE CONDITIONS**

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### **Climate Considerations**

The National Climate Assessment (NCA) report (Garfin, et.al., 2014) notes that one of the anticipated impacts of climate change for the Southwest is a reduction in average annual precipitation and streamflow volumes. The report and supporting documents also indicate that winter storm intensities are anticipated to increase, which may lead to increased event-based flooding. The NCA report also notes that winter precipitation will be less in the form of snow and more frequently rain. For Northern Region communities, the impacts could result in more severe winter season flooding.

A second study by Luong (Luong, et. al., 2015), notes that monsoon thunderstorms in the Central and Southern Regions of the state have become more intense over a recent 20 year period (1991-2010) when compared to events recorded in the past (1950-1970). The study concludes that the trend will likely continue as the temperatures rise and provide more moisture storage capacity in the lower atmosphere. The increased intensities may result in increased flood levels.

Statewide, the overall flooding conditions could also be exacerbated by watersheds with reduced vegetation due to increases in drought or wildfire conditions.

### **Changes in Development**

Anticipated flooding impacts due to future development and land-use planning changes for each region, are generally obtained from the county hazard mitigation plans. All 15 counties and the incorporated communities generally require adherence to modern building codes and actively regulate their respective floodplains for new developments or substantial re-development. The majority of flood prone properties pre-date the state and counties' entry into the NFIP program and will continue to be areas of focus and attention. Development and population growth into known and unknown floodplains can increase the future probability of an event. State-owned facilities primarily impacted by future changes in development generally include the freeways and highways and their supporting culverts and bridges. Unless otherwise noted, reference to a county also includes the incorporated communities within that county.

### **North Region**

Apache, La Paz, and Navajo Counties have experienced little to no growth of any significance over the past five years, nor is there any major growth or development in flood prone areas anticipated over next five years. Moderate growth has occurred in Coconino, Mohave, and Yavapai Counties and the trends of the past five years are anticipated to continue into the future with most of the growth being centered around existing population centers. Areas of anticipated significant growth that may extend into flood hazard areas are identified in the Flagstaff and Tusayan (Coconino), Prescott Valley



and Chino Valley (Yavapai), Kingman, Bullhead City and Lake Havasu City (Mohave), plus several populated areas within the unincorporated areas of Coconino, Mohave, and Yavapai Counties.

### Central Region

Moderate growth has occurred in Maricopa and Pinal Counties over the past five years, and primarily in the build-out of previously planned residential, industrial and commercial areas. Growth in Gila County has been mostly limited to the Payson area. Maricopa County has a well-established flood control district with strong modeling, mapping, planning and construction programs to better inform the public of flood risks and reduce risk in flood prone areas. Planned growth in Pinal County areas subject to flooding is anticipated in or near Maricopa and Casa Grande, and the unincorporated areas north of Florence along Hunt Hwy and downstream of the San Tan Mountains.

### South Region

Pima and Yuma Counties have experienced moderate growth over the past 5-years in some locations and population declines in others. Cochise County experienced moderate growth within Douglas and Sierra Vista, but generally a decline in the overall population. Graham County saw limited growth that is mostly attributable to the development of the new Freeport McMoRan mining operations. Santa Cruz and Greenlee Counties have experienced limited to no significant growth. Pima and Yuma Counties have well-established flood control districts with strong modeling, mapping, planning and construction programs, and they work closely with their incorporated communities to better inform the public of flood risks in their area and reduce risk in flood prone areas. Future growth into flood prone areas within Cochise, Graham, Greenlee, Santa Cruz, and Yuma County's is not anticipated to be significant.

## VULNERABILITY ASSESSMENT

The estimation of potential exposure to the identified high and medium flood hazards was accomplished by using GIS tools to intersect the human and state-owned critical facilities and infrastructure (CFI) data with the flood hazard limits as depicted on the profile maps that follow. The loss calculations assume that no structure will be flooded to a depth of greater than two-feet on average, and per the FEMA tables, are subject to a loss-to-exposure ratio of 0.20 (or 20% damaged). The loss estimates presented are based on a single event and assume that the entire region is flooded to the depicted hazard at the same time. No losses are estimated for assets located in the medium flood hazard areas

### North Region

The North Region has the most RL and SRL properties, but the region is the least vulnerable to flood hazards when considering the number of historic declarations and exposure estimates.

#### State-Owned CFI Exposure and Loss Estimates

A total of 38 state-owned CFI, or 17.8% of the statewide exposure, are located within a high hazard area. The exposed facilities represent a total exposed replacement value of \$10.8 million, with an estimated \$2.2 million in potential losses. For the medium flood

hazard, a total of 68 state-owned CFI, or 5.8% of the statewide exposure, are exposed and represent a total replacement value of \$15.5 million. No losses are estimated for facilities exposed to a medium flood hazard.

Additional state-owned facilities vulnerable to flood hazards are the AZ Dept of Transportation (ADOT) operated and maintained freeways, highways and state routes. The majority of ADOT roadway corridors in the rural areas are designed to handle at least a 2% annual flood (50-year), which means a 1% annual flood may overtop or exceed the constructed drainage facilities. There are numerous drainage facilities (bridges, culverts and channels) constructed with the ADOT roadways. Typical impacts might include erosion of roadway embankments and pavements, culvert failures, and potential bridge failure.

### Vulnerable Population Groups

The 2015 estimated total population for the North Region is 772,157 people. Approximately 5.46% and 5.04% of the total population, or 42,159 and 38,884 persons, are exposed to high and medium flood hazards.

On average, approximately 7.3% of the North Region population is estimated to have a Limited English Proficiency (LEP) (US Census Bureau, 2016). Assuming the percentage is equally applied across the whole region's population, roughly 3,077 and 2,838 LEP persons (7.3% of 42,159 and 38,884) are estimated to be exposed to high and medium hazard flooding.

### Local Jurisdiction Vulnerability

Local hazard mitigation plans for the North Region identified a total of 253 assets with a total replacement value of \$1.86 billion. Total potential losses to local CFI were estimated at \$372 million.

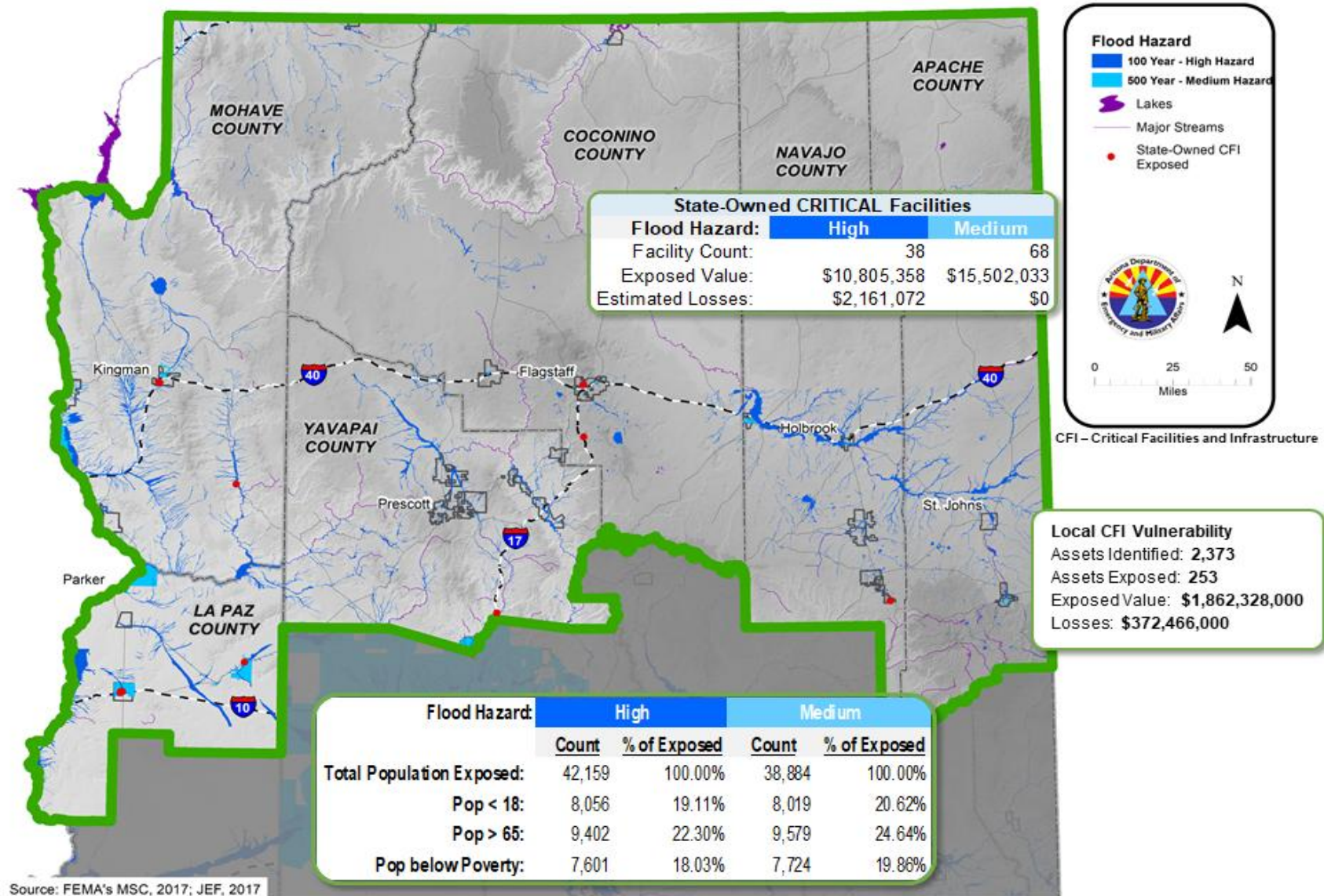
### Specific Areas of Concern

Existing development statewide that was built before the floodplain standards were enacted remain vulnerable to regular flooding. Flood regulations and elevation requirements have typically only been applied to new structures built after the mid-1980s. Historic cities and towns in Arizona were often built near rivers or other regional watercourses within areas that face periodic flooding. Several small towns in the North region face elevated flood risk due to their location near rivers or major washes. The Town of Wenden in La Paz County is located adjacent to Centennial Wash and has experienced two major floods in the year 2000 and 2010. Winslow and Holbrook are communities in Navajo County that face elevated flood risk due to their proximity to the Little Colorado River and their reliance upon aging levees and associated infrastructure that is very expensive to fix. The Rio de-Flag running through the middle of Flagstaff is constant source of flooding with significant damages in 2014, 2010, and 2004.

One area of particular concern to many of the North Region communities is the possibility for significant post-wildfire flooding. Coconino County is performing advanced post wildfire planning and risk assessments for the communities of Williams and Fort Valley to develop action plans and formulate pre-disaster mitigation strategies.

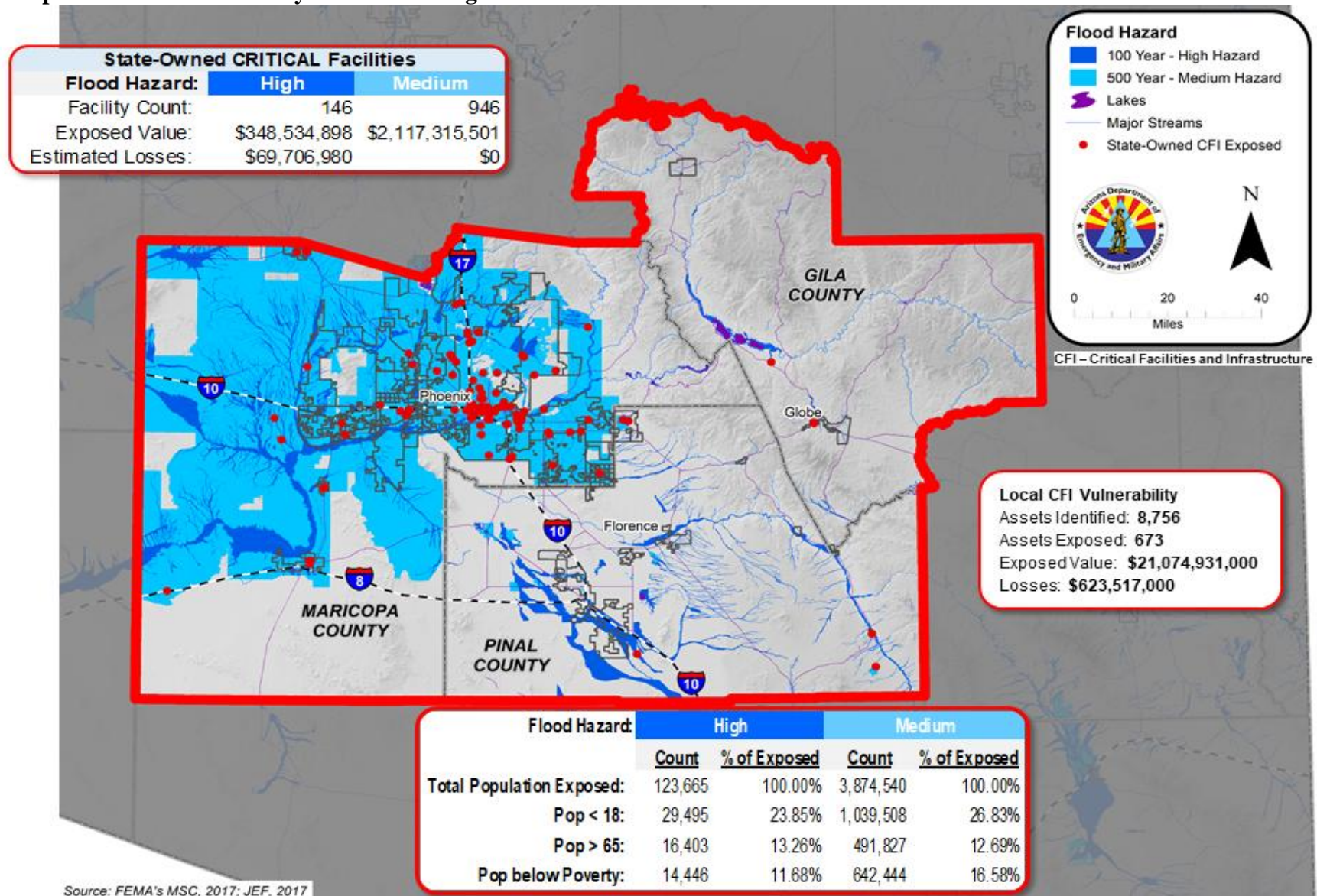
Another challenge unique to the North Region is flood risk management on tribal lands. Many of the tribal population areas are remote and easily isolated with regular flood events. Cultural and economic limitations make flood risk reduction measures difficult and leave significant tribal populations at risk.

Map 22: Flood Vulnerability for North Region





Map 23: Flood Vulnerability for Central Region





## Central Region

Among the three state regions, the Central Region has the most significant vulnerability to flood hazards when considering the number of historic declarations, exposure estimates, and RL/SRL properties. Alternately, the Central Region arguably has the greatest amount of resources for active flood mapping, modeling and mitigation.

### State-Owned CFI Exposure and Loss Estimates

A total of 146 state-owned CFI, or 68.5% of the statewide exposure, are located within a high hazard flood area. The exposed facilities represent a total exposed replacement value of \$348.5 million, with an estimated \$69.7 million in potential losses. For the medium flood hazard, a total of 946 state-owned CFI, or 80.4% of the statewide exposure, are exposed and represent a total replacement value of \$2.12 billion. No losses are estimated for facilities exposed to a medium flood hazard.

Roadways and infrastructure within the metropolitan Phoenix area are designed to meet local drainage requirements, and therefore are protected to 1% annual flood level. There are numerous drainage facilities (bridges, culverts and channels) constructed with the ADOT roadways. Estimation of losses is difficult, but historic losses give some indication of the potential for future losses. During the 1993 flood, the Federal Highway Administration provided over \$28.3 million in financial assistance to fix damaged roads in the Central Region (USACE, 1994). Therefore, losses exceeding \$29 million are feasible.

### Vulnerable Population Groups

The 2015 estimated total population for the Central Region is 4,604,414 people. Approximately 2.69% and 84.16% of the total population, or 123,665 and 3,874,540 persons, are exposed to high and medium flood hazards. Each of the vulnerable population groups analyzed were at approximately 12-24% of the total population exposure to high hazard flood risk and roughly 12-27% of the total population exposure to medium hazard flood risk.

On average, approximately 6.7% of the Central Region population is estimated to have a Limited English Proficiency (LEP) (US Census Bureau, 2016). Assuming the percentage is equally applied across the whole region's population, roughly 8,286 and 259,594 LEP persons (6.7% of 123,665 and 3,874,540) are estimated to be exposed to high and medium hazard flooding.

### Local Jurisdiction Vulnerability

Local hazard mitigation plans for the Central Region identified a total of 673 assets with a total replacement value of \$21.1 billion. Total potential losses to local CFI were estimated at \$624 million.

### Specific Areas of Concern

Existing development that was built before the floodplain standards were enacted remain vulnerable to regular flooding. Older areas of the Phoenix Metropolitan area experience local flooding due to the lack of adequate drainage facilities, and especially in areas adjacent to canal systems crossing through the valley. In the western portion of Pinal

County, the City of Maricopa and surrounding communities face a flood risk from several regional watercourses that comprise the Lower Santa Cruz River system

## **South Region**

Among the three state regions, the South Region is the second most vulnerable to flood hazards. The Tucson Metropolitan area of the South Region has significant resources for active flood mapping, modeling, and mitigation in those areas. The more rural areas, however, are not as equipped. Of the three state regions, the South Region has the least amount of RL/SRL properties but is considered to be the second most vulnerable region.

### **State-Owned CFI Exposure and Loss Estimates**

A total of 29 state-owned CFI, or 13.6% of the statewide exposure, are located within a high hazard area. The exposed facilities represent a total exposed replacement value of \$9.1 million, with an estimated \$1.8 million in potential losses. For the medium flood hazard, a total of 163 state-owned CFI, or 13.8% of the statewide exposure, are exposed and represent a total replacement value of \$283.5 million. No losses are estimated for facilities exposed to a medium flood hazard.

Roadways and infrastructure within the metropolitan Tucson area are designed to meet local drainage requirements, and therefore are protected to 1% annual flood level. There are numerous drainage facilities (bridges, culverts and channels) constructed with the ADOT roadways. During the 1993 flood, the Federal Highway Administration provided over \$29.4 million in financial assistance to fix damaged roads in the South Region (USACE, 1994). Losses exceeding \$30 million are certainly feasible with a significant storm event.

### **Vulnerable Population Groups**

The 2015 estimated total population for the South Region is 1,458,367 people. Approximately 5.74% and 16.93% of the total population, or 83,738 and 246,969 persons, are exposed to high and medium flood hazards. Each of the vulnerable population groups analyzed were at approximately 17-25% of the total population exposure to high hazard flood risk and roughly 15-28% of the total population exposure to medium hazard flood risk.

On average, approximately 12.7% of the Central Region population is estimated to have a Limited English Proficiency (LEP) (US Census Bureau, 2016). In Santa Cruz and Yuma, this number averages 23.5%. Assuming the percentage is equally applied across the whole region's population, roughly 10,635 and 31,365 LEP persons (12.7% of 83,738 and 246,969) are estimated to be exposed to high and medium hazard flooding.

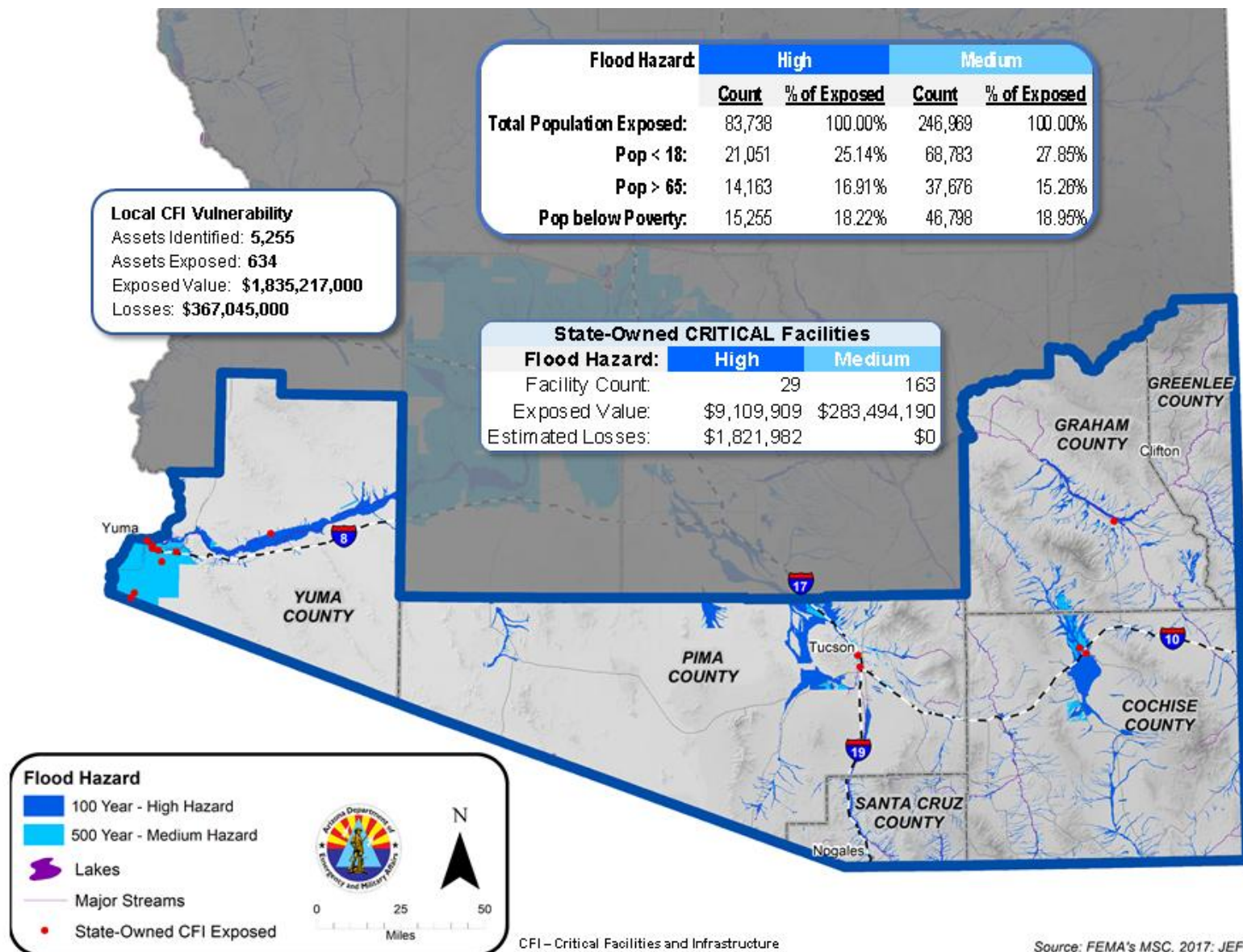
### **Local Jurisdiction Vulnerability**

Local hazard mitigation plans in the South Region identified a total of 634 assets with a total replacement value of \$1.84 billion. Total potential losses to local CFI were estimated at \$367 million.

### Specific Areas of Concern

Existing development that was built before the floodplain standards were enacted remain vulnerable to regular flooding. Older areas of the Tucson Metropolitan area experience local flooding due to the lack of adequate drainage facilities, and especially in areas near downtown Tucson and the older neighborhoods around the University of Arizona. Nogales Wash in Nogales and Santa Cruz County, is a high risk flood corridor that is complicated by a failing underground tunnel and concrete lining, and the presence of regional wastewater system located in bed of the wash that when breached, spills millions of gallons of raw sewage into the watercourse. The Town of Patagonia is another Santa Cruz County community that is impacted by a significant flood hazard that covers a substantial portion of the town limits. In the Town of Clifton, repeated flooding of Ward's Canyon in 2005, 2010, and again in 2015 threatens several critical facilities. A significant portion of the Town of Duncan will be inundated with any Gila River flows exceeding a 10% annual flow (10-year Flood). The citizens of the Town of Sahuarita are subject to being cut off from emergency services when flooding occurs in the Santa Cruz River and several other washes and channels in the area.

Map 24: Flood Vulnerability for South Region



## POTENTIAL CONSEQUENCES AND IMPACTS

### Public

Populations that experience flooding are often faced with difficult physical, mental, and economic concerns. As demonstrated by Arizona's past flood events, the impact to the general public is typically property damage and loss, injury, and in some cases, death. Flood events can often force populations to relocate until the floodwaters recede as their homes are impacted by the flood waters. Even after the water recedes, homes can be unlivable until they are repaired and cleaned of mud, debris and potential mold. Often these floods result in the loss of personal possessions that cannot be salvaged after they are damaged by flood waters.

Several of the deaths, injuries, and rescues associated with flooding often took place when citizens attempted to drive across high or moving waters. Potential dangers include electrical hazards, carbon monoxide exposure, musculoskeletal hazards, heat or cold stress, motor vehicle-related dangers, fire, drowning, and exposure to hazardous materials. Other factors in flood-related injuries, illness, and death include disease as a result of unhygienic conditions and water-borne diseases. A review of flood-related fatalities from 13 flood events in the United States and Europe, found that 68% of the deaths from flooding were due to drowning, 12% trauma, and 6% heart attack among other causes<sup>14</sup>.

In addition to physical injuries, flooding victims suffer the psychological impacts of flooding. A recent study of flood victims in the United Kingdom found that 27% of flood victims met the criteria for symptoms associated with Post Traumatic Stress Disorder and over 35% had symptoms of depression<sup>15</sup>.

### Responders to the Incident

Clean-up activities following floods often pose hazards to workers and volunteers involved in the effort. Potential dangers include electrical hazards, carbon monoxide exposure, musculoskeletal hazards, heat or cold stress, motor vehicle-related dangers, fire, drowning, and exposure to hazardous materials. Because flood disaster sites are unstable, clean-up crews might encounter sharp debris, biological hazards, exposed electrical lines, blood or other body fluids, and animal and human remains. Responders are prone to the same dangers the general public is, but at a higher level as they may be putting themselves in harm's way by performing rescue activities.

### Continuity of Operations/Delivery of Services

Public Safety, Military, and Department of Transportation have facilities located in flood-prone areas and would be critical to response and recovery efforts. For example, ADOT has a facility in Safford within the high hazard flood zone on US 70. This facility includes a DPS radio building. Academia and Corrections are important, but not likely to be critical. Much of the Arizona State University infrastructure is located in Tempe, in a medium hazard zone. The Department of

<sup>14</sup> Doocy, S., Daniels, A., Murray, S., & Kirsch, T. (April, 2013) The Human Impact of Floods: A Historical Review of Events 1980-2009 and Systemic Literature Review, PLOS Current Disasters.

<sup>15</sup> Mason, V., Andrews, H. and Upton, D. (2010). *The Psychological Impact of Exposure to Floods*. Journal of Psychology, Health & Medicine. (pp 61-73)



Economic Security facility may be critical if it is necessary for public assistance payments during an event. One of these buildings is located in a medium hazard flood zone in Kingman, AZ. The Continuity of Operations and Delivery of Services of any of these structures will depend on the severity of the flooding and how much damage the facility sustains.

### **Environment/Cultural**

Water supplies threatened by flood events can become contaminated, resulting in public health, food supply, and livestock issues. Flood contaminants may include raw sewage, chemicals, oil, and bacteria that can all pose a risk to human health. Mold growth in flooded structures can be a significant health detriment to many and especially those with mold toxicity issues. On the positive side, natural flooding can provide environmental benefits such as increasing soil fertility and recharging aquifers.

Culturally, floods can impact cultural landmarks of a community through both inundation and erosion processes. In some cases, tribal cultural resources and archeological sites can be located in or near major watercourses and can be destroyed with large flooding events. Flooding of local churches and community recreational facilities can also have a negative influence on a community's cultural health.

### **Economic/Financial Condition of Jurisdiction**

Recovery and rebuilding costs, a decline in tourism, food shortages, lack of infrastructure, and the effects on local economies are a few of the contributing factors to economic hardship for the State due to flooding. Businesses impacted by flooding may face the loss of income during the flood, combined with the cost of rebuilding. These issues may cause some businesses in a community to permanently relocate from the area. Agricultural losses due to flooding are also significant and can harm rural areas. Some areas may be isolated as flood waters can damage the transportation infrastructure. It may take significant time and resources for a community to restore full access.

### **Public Confidence in Jurisdiction's Governance**

The speed of emergency response, efficiency, and communication are key factors in maintaining public confidence during and after a flood event. The effects of flooding are destructive and disruptive to jurisdictions and often continue after the immediate event has passed. Power outages are likely, and travel may be hindered due to flood waters, debris, and blocked roads. Some government functions may be reduced or lost during a significant flood event. Public employees may be removed from normal duties to help in the response and recovery efforts, putting some less critical government operations on hold. Public facilities may be impacted by the flooding, causing services to be relocated or suspended until the agency can recover.

### **Cascading/Secondary Impacts**

Flooding can have numerous secondary impacts. As described in the section above, the initial flood incident can often predicate many other environmental, financial and social impacts, and particularly where flooding is widespread. Residents may be dislocated for long periods of time as their homes are being repaired. In some cases, they may not have the money to rebuild or may face permitting obstacles. The length of this disruption can cause permanent changes to the fabric of the community, as people may temporarily or permanently relocate. Contaminated wells may create large expenses for municipalities and homeowners that are looking to rebuild.

Lateral migration of watercourses in areas of historic landslides, can expose the toe of a long dormant slide area and trigger a brand new slide. Repeated flooding of overbank areas can encourage growth of grasses and small brush vegetation that when dried, can act as ladder fuels and ignition sources for river bottom wildfires.

## RESOURCES

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## HAZARDOUS MATERIALS INCIDENTS

A hazardous material is any substance or material in a quantity or form that may pose a reasonable risk to health, the environment, or property. The US Department of Transportation defines hazardous materials as belonging to one of nine hazard classes (USDOT BTS, 2015), as follows:

- Class 1—Explosives
- Class 2—Gases
- Class 3—Flammable Liquids
- Class 4—Flammable Solids
- Class 5—Oxidizing Substances and Organic Peroxides
- Class 6—Toxic Substances and Infectious Substances
- Class 7—Radioactive Materials
- Class 8—Corrosive Substances
- Class 9—Miscellaneous Hazardous Materials



Hazardous materials spill incidents may involve any of the above classes of materials. Accidental or incidental releases of hazardous materials typically are associated with fixed facility incidents and transportation-related accidents.

In the case of fixed facility incidents, the hazards are usually pre-identified, and each facility is required by Arizona law to prepare a risk management plan and provide a copy to the local emergency planning committee (LEPC) and local fire departments. Arizona Tier II forms must also be filed with the Arizona State Emergency Response Commission (AZSERC) at the Arizona Department of Environmental Quality (ADEQ). For specific site plans, each county LEPC is required by law to maintain a copy of these plans.

The prediction of the exact location of transportation related hazardous materials incidents is not possible; however, certain routes are likely to carry greater amounts of materials at greater frequencies, such as interstates, major highways and railways. The close proximity of railroads, highways, airports, waterways, pipelines, and industrial facilities to populated areas, schools, and businesses could put a large number of individuals in danger at any time. In addition, essential service facilities, such as police and fire stations, hospitals, nursing homes, and schools near major transportation routes are also at risk from potential hazardous materials transportation incidents.

Increased use and transport of materials across the country has created serious problems for emergency services personnel. Many factors can increase the magnitude of an otherwise simple transportation accident into an incident of potential threat to high numbers of people. For example, over 14,000 different chemicals are estimated as being shipped by various transportation modalities. Some types of highly toxic chemicals do not require placarding if shipped in quantities of less than 1,000 pounds, even though lesser quantities could devastate a small town.



In addition to traditional chemical hazards, radiological incidents could be a legitimate threat to populations in Arizona. Transport of radioactive materials presents the most probable scenario for a radiological incident. The US Department of Energy is currently shipping radioactive waste by truck to repositories in Texas and Utah. Training and equipment for responding to peacetime radiological incidents are usually relegated to organizations located in the cities and counties near the more metropolitan areas or sites with radiological sources, leaving potentially large response times for incidents that may occur in remote areas of the state.

The federal government has finalized development of long-term repositories for spent fuel, transuranics (TRU), and other high-level radioactive wastes, at Yucca Mountain, Nevada, and Carlsbad, New Mexico. Speculations have suggested that up to 3,600 shipments per year may go to these facilities.

In addition to transportation, radiological incident scenarios could involve faulty re-entry of nuclear-equipped satellites to earth (such as COSMOS 954 in 1978 and SKYLAB in 1980). The probability of this happening and impacting an area in Arizona is highly unlikely; however, there are known to be at least 53 (Johnson, 2005) nuclear powered satellites existing within Earth's orbit.

As a fixed facility with the potential for catastrophic radiological releases, the Palo Verde Generating Station (PVGS), located on 4,250 acres near Wintersburg, approximately 55 miles west of downtown Phoenix, is the largest nuclear energy facility in the United States. It is operated by Arizona Public Service and owned by a consortium of seven utility companies.

## HISTORY

According to the US Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA), more than 2.5 billion tons of regulated hazmat, including explosive, poisonous, corrosive, flammable, and radioactive materials valued at about \$2.3 trillion, is moved 307 billion miles annually on the nation's interconnected transportation network.

Starting with reporting on 2002 incidents, the US Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA) defines "serious incidents" as incidents that meet one or more of the following criteria:

- A fatality or major injury caused by the release of a hazardous material,
- The evacuation of 25 or more persons as a result of release of a hazardous material or exposure to fire,
- A release or exposure to fire which results in the closure of a major transportation artery,
- The alteration of an aircraft flight plan or operation,
- The release of radioactive materials from Type B packaging,
- The release of over 11.9 gallons or 88.2 pounds of a severe marine pollutant, or



Nogales Wash – International Outfall Interceptor rupture at manhole location in Nogales, AZ  
Source: AZ Governor's Office, 2017

- The release of a bulk quantity (over 119 gallons or 882 pounds) of a hazardous material.

Since 1978, there have been a total of six state declarations related to hazardous materials incidents. Four were incident specific, and two were more general statewide declarations. A total of \$3.3 million in state funds were expended in response to the declarations. Details for the four incident specific declarations, along with other examples of significant hazardous material incidents that have occurred in the last ten years, are as follows:

- July 27, 2017 - Arizona declared a state of emergency following the rupture of the International Outfall Interceptor sewage conveyance pipeline near Nogales. The rupture was caused by flooding from a monsoon thunderstorm that displaced a manhole riser and broke the pipe beneath. Raw sewage was released directly into Nogales Wash, requiring in-stream chlorination measures (AZ Governor's Office, 2017).
- May 22, 2017 - A release of ammonia solution vapors from a plastic 55-gallon drum storage drum at a FedEx Freight Facility located on Lower Buckeye Road in Phoenix. The release caused two employees to go to the hospital due to inhalation and the Phoenix Fire Department evacuated approximately 100 people from the dock for approximately 1.5 hours (NRC, 2018).
- June 10, 2014 - A faulty valve on a rail car released approximately 10 tons of anhydrous ammonia to the atmosphere at the load-off area of the Apache Nitrogen Products facility in St. David, Arizona. Eleven people were injured and three required hospitalization (NRC, 2018).
- April 17, 2013 - A chemical spill of potassium ferrous cyanide mixed with hydrochloric acid occurred during a chemistry class at Flagstaff High School in Flagstaff. The two chemicals reacted and caused a release of hydrogen cyanide gas. Approximately 600 students and faculty were evacuated, and one teacher and one student were injured (NRC, 2018).
- July 28, 2012 - A rail car released 20,000 gallons of a corrosive liquid in Hayden. The spill did not result in any deaths or injuries but did result in over \$400,000 in damages.
- May 21, 2011 - A fuel tanker was involved in an accident on SR347 and released over 2,000 liquid gallons of gasoline. Four people were taken to the hospital with injuries that resulted from the accident. This spill generated damages in excess of \$7 million.
- March 23, 1999 - Arizona declared a state of emergency to remove, dispose and remediate a large quantity of explosives and dangerous reactive chemicals discovered in September 1997 by the Bureau of Alcohol, Tobacco and Firearms (BATF), at the Star Flash Ranch in New River. Operations were completed, and the site was secured by July 1999 at an expense of \$326,000 (Schamadan, 1999; DEMA, 2017).
- January 16, 1980 - Arizona declared a state of emergency for the 17-acre Mountain View Mobile Homes site near Globe which was developed in 1973 on the site of the former Metate Asbestos Corporation's chrysotile asbestos mill. In 1979, asbestos contamination was discovered, with small piles of asbestos mill tailings found against the abandoned mill structures and the adjacent railroad tracks. The site was ultimately made a superfund site by the EPA with an approximate relocation and remediation cost of \$4.3 million (EPA, 1983).



- September 25, 1979 - Arizona declared a state of emergency regarding reports of radioactive tritium leaks at the American Atomic Energy plant in Tucson. Chocolate cake made in the school across the road from the plant was found to have 56,000 picocuries per liter of radioactive tritium, almost three times the official safe standard set by the EPA for water. A reported \$300,000 worth of food was contaminated by the radioactive tritium (<http://prop1.org/2000/accident/facts4.htm>).

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## PROBABILITY/EXTENT

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The probability of hazardous materials incidents occurring within the state is very high; however, PHMSA-defined "serious incidents" with injuries or fatalities caused by the force of the accident versus exposure to hazardous materials, is low to moderate. Additionally, large scale hazardous material incidents are uncommon.

According to a 2010 study (HDR, 2010), the most commonly transported hazardous materials reported include gasoline, liquid propane gas, diesel, sulfuric acid, ammonium nitrate, pesticides, and copper concentrate products. These materials have the potential to cause serious health and environmental damage in the event of an accidental release

In 2006, AZSERC commissioned a commodity flow study (AMEC, 2006) of the Interstate 8 and 10 corridors, several arterial highways, and adjacent railroad segments. Placarded truck surveys indicated that, on average, 5.3% of the commercial trucks observed in the I-10 study area (approximately 3,500-4,500 trucks per day) contained hazardous materials. There were 78 different hazardous materials recorded during the placarded truck surveys, with gasoline, combustible liquid, and butane being the most common. Along I-10, Class 3 (flammable liquids) accounted for 45.3% of all recorded hazardous materials. Class 2 (gases) accounted for 18.9% and Class 8 (corrosive substances) accounted for 16%. Six extremely hazardous substances (EHS) - sulfuric acid, hydrazine, hydrogen chloride, hydrogen fluoride, nitric acid, and propylene oxide - were recorded in the I-10 study area. Rail transport of hazardous materials was also noted in the study and offered similar conclusions.

The US Coast Guard administers the National Response Center (NRC) – a multi-modal, multi-causality repository of reported HazMat related incidents. The NRC database was queried for incidents occurring in the last five-years (2013-2017). Over that period, a total of 817 incidents were logged and resulted in a total of 1,624 evacuees, 141 injuries – 97 of which required hospitalization, 17 fatalities and total damages to property estimated at \$587,891. Details of the incidents distributed by Arizona planning region are shown in profile maps that follow. Also shown on the maps are the primary roadway and railway transportation routes, international points of entry with Mexico, and the general location of the Palo Verde Generation Station and its 10-mile emergency planning zone.

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## WARNING TIME

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Hazardous material incidents occur without warning, and depending on the material type and ambient conditions, the propagation or spread of the released hazardous materials can also happen very quickly, leaving little to no warning for evacuation measures.

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## **FUTURE CONDITIONS**

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### **Climate Considerations**

Future climate changes are not anticipated to have any direct impact on the occurrence of hazardous material incidents.

### **Changes in Development**

In general, changes in development correlate to the threat of hazardous materials incidents in the form of changed exposure to people, animals, and to a lesser extent, infrastructure. Development tends to follow major roadways, or even create new major roadways and increase the number of corridors of potential transport of hazardous materials.

#### **North Region**

North Region growth areas of significance are anticipated to primarily center around Flagstaff, Kingman, Bullhead City, and Lake Havasu City and the unincorporated areas surrounding these communities. The rest of the area is not anticipating significant growth over the next five years.

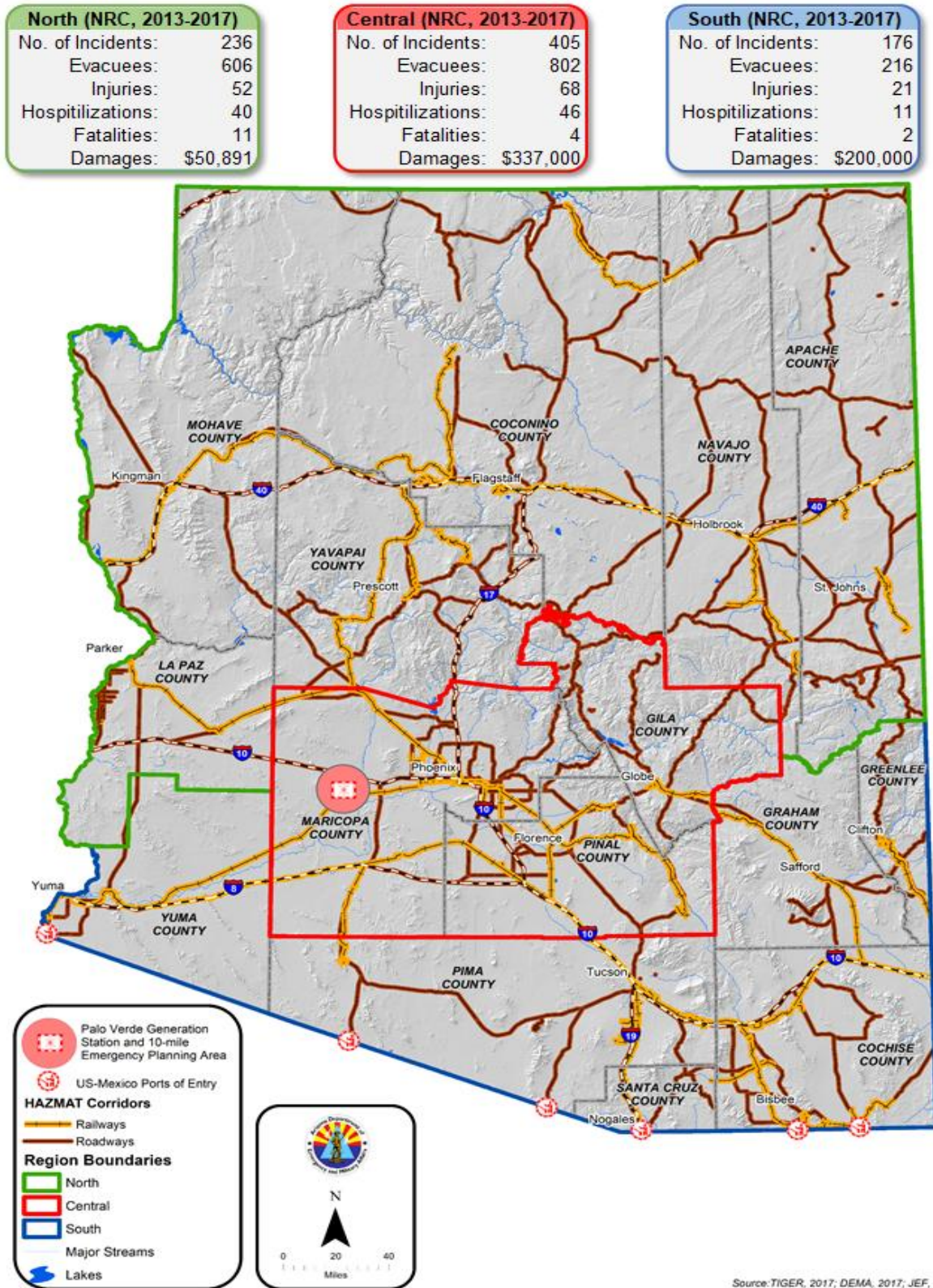
#### **Central Region**

The highest growth areas in the state are located within the Phoenix Metropolitan area of Maricopa County, with development occurring along the fringe areas. Growth to the west of Phoenix will continue to edge closer to the PVGS facilities. The continued growth of industry will also require increased deliveries of potentially hazardous materials. For example, Nikola Motor Company has recently announced plans to build a one-million-square-foot manufacturing plant for its hydrogen-electric semi-trucks in the western limits of Buckeye AZBEX, 2017), which will likely lead to an increase in the flow of certain hazardous material through an area that historically would not have seen any.

#### **South Region**

Improvements in the economy over the last five years have resulted in an increase of trade and movement of hazardous materials across the US-Mexico border, especially at the Nogales, San Luis, and Douglas points of entry. The increased trade has increased exposure to population and properties located along the routes heading north. Also, growth in the form of development in the Tucson Metropolitan area has increased the exposure and those trends are expected to continue.

**Map 25: Hazardous Materials Transportation Corridors Statewide**



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## VULNERABILITY ASSESSMENT

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Historically, common hazardous materials incidents do not pose a significant threat to the state-owned facilities and infrastructure.

### North Region

The North Region is considered the least vulnerable to hazardous materials incidents, primarily since the North has the least population, the lowest concentration of Tier II facilities, and that the majority of past significant hazardous materials incidents are primarily associated with traffic accidents along I-40 and I-17.

#### State-Owned CFI Exposure and Loss Estimates

All 1,988 state-owned facilities representing \$2.4 billion in replacement value are considered exposed to hazardous materials incidents, and several may be classified as Tier II facilities. No losses are estimated.

#### Vulnerable Population Groups

The entire 2015 estimated population of 772,157 people are considered as exposed to hazardous materials incidents, with the populations along I-40 and I-17 and the adjoining BNSF Railway being at the greatest risk. The exposed sub-group populations include 177,450 persons (23.0% of region total) under 18 years of age, 158,170 persons (20.5% of region total) older than 65, 163,483 persons (21.2% of region total) living at or below poverty level, and an LEP population of 56,625 (7.3% of region total).

#### Local Jurisdiction Vulnerability

Coconino, La Paz, Mohave, and Navajo Counties all included hazardous materials incidents in their mitigation plan risk assessment. Conclusions of the vulnerability analyses are similar to what is presented in this Plan.

#### Specific Areas of Concern

Camp Navajo near Bellemont was originally established as Navajo Ordnance Depot in 1942. Total construction of the facility was completed in less than one year and included, 800 ammunition storage igloos, 50 administrative buildings, 227 miles of road, 38 miles of railroad track, and completed utility distribution and collection systems. In 1993, the US Department of Defense moved the US Army federal ammunition mission to Hawthorne Army Ammunition Plant in Nevada and transferred the installation to the Arizona National Guard. Expansion of the storage utility can see movement of hazardous materials into and out of the facility by both rail and road.

### Central Region

The Central Region is considered the most vulnerable to hazardous materials incidents due to having the highest population density, the highest concentration of Tier II facilities, and the significant impacts associated with the variety of materials move in, out, and through the Phoenix Metropolitan area. The PVGS is also located within the Central Region.



### State-Owned CFI Exposure and Loss Estimates

All 3,464 state-owned facilities representing \$9.0 billion in replacement value are considered exposed to hazardous materials incidents, and indeed several may be classified as Tier II facilities. No losses are estimated.

### Vulnerable Population Groups

The entire 2015 estimated population of 4,604,414 people are considered as exposed to hazardous materials incidents. The exposed sub-group populations include 1,216,158 persons (26.4% of region total) under 18-years of age, 618,612 (13.4% of region total) persons older than 65, 748,257 persons (16.3% of region total) living at or below poverty level, and an LEP population of 306,961 (6.7% of region total).

### Local Jurisdiction Vulnerability

Gila and Maricopa Counties addressed hazardous materials incidents in their mitigation plan risk assessment. The Maricopa County mitigation plan evaluated hazardous materials incidents in their Emergency Management Accreditation Program annex. Conclusions of the vulnerability analysis for both plans are similar to what is presented in this Plan.

### Specific Areas of Concern

Although improbable, the consequence of a significant radiological incident at the PVGS would be catastrophic for the region and state. On a more probable basis, the continued influx of new industry to the region will also bring new hazardous materials and increased hazardous material transportation.

## South Region

The South Region is considered the second-most vulnerable to hazardous materials incidents due to the moderately-high population density, major road and rail transportation corridors, the second highest concentration of Tier II facilities, and the US-Mexico border challenges.

### State-Owned CFI Exposure and Loss Estimates

All 1,505 state-owned facilities representing \$5.2 billion in replacement value are considered exposed to hazardous materials incidents, and indeed several may be classified as Tier II facilities. No losses are estimated.

### Vulnerable Population Groups

The entire 2015 estimated population of 1,458,367 people are considered as exposed to hazardous materials incidents. The exposed sub-group populations include 354,191 persons (24.3% of region total) under 18-years of age, 242,700 (16.6% of region total) persons older than 65, 268,372 persons (18.4% of region total) living at or below poverty level, and an LEP population of 306,961 (6.7% of region total).

### Local Jurisdiction Vulnerability

Santa Cruz County is the only South Region county to address hazardous materials incidents in their mitigation plan risk assessment which focuses on the concentration of



road and rail threats at the border community of Nogales. Other conclusions of the vulnerability analysis are similar to what is presented in this Plan.

### **Specific Areas of Concern**

As with the Central Regions, growth of industry in the Tucson Metropolitan area will include increases in the exposure and transport of hazardous materials to service those industries. The materials crossing the US-Mexico border are heavily regulated, but increased trade with Mexico will include increases in the amount of hazardous materials moved.

## **POTENTIAL CONSEQUENCES AND IMPACTS**

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### **Public**

The impact to the public from hazardous materials incidents can range from minor to catastrophic and can have a long-term negative impact after the incident is over. In the past, hazardous materials incidents have caused injury, disease, and death. Numerous facilities that manufacture, ship, and store extremely hazardous chemicals reside within cities limits or highly populated urban areas. A hazardous materials release can have long-term effects on natural resources and permanently restrict the public from utilizing these resources. Incidents can have a serious impact on air and water quality, property acquisition, fish, and wildlife, agricultural and farming which will present serious long-term problems for the public. As demonstrated in the past, hazardous materials events involving chlorine releases, radioactive waste material, volatile chemicals and toxic materials have proven extremely painful to the public, both physically and financially.

### **Property/Facilities/Infrastructure**

Except for incidents involving explosions or the potential for longer-term radiological exposure, the impact of hazardous materials incidents to physical structures, buildings, and infrastructure are minimal.

### **Responders**

An incident often produces toxic clouds that drift and settle on the ground and in the drinking water systems causing extensive clean-up activities. Clean-up activities following hazardous materials incidents are often dangerous and expensive. It is not only the incident and the immediate effects, but people in the contamination zone and initial responders often suffer from long-term health problems due to the hazardous materials release. Environmental concerns do not end when the last responder leaves. A process of decontaminating effected ecosystems can take years and often pose additional health hazards to workers and volunteers involved in these efforts. Potential dangers include kidney disease, lung infections, various types of cancer, and respiratory disease and failure. Long-term risk of disease or illness could cost taxpayers millions of dollars in recovery costs and rehabilitation, not to mention legal costs associated with the incidents. These incidents could also have a significant effect on law enforcement as they try to secure an area, emergency medical systems as they try and move and treat the injured, and hospitals as they attempt to triage and treat persons contaminated with hazardous substances.

### **Continuity of Operations/Delivery of Services**

The size and duration of a hazardous materials incident could seriously drain local capabilities and require additional resources and support from hazardous materials trained responders. Short of a major radiological incident, most accidents and spills are fairly localized and are not expected to significantly impact the state's ability maintain operational status.

### **Environment/Cultural**

After a hazardous materials incident, the environment could suffer from long lasting serious negative impacts. Agriculture, hydrology, urban settlements, economic activities, and health and welfare of the populace would all be impacted during a catastrophic event. Contamination of water supplies could be devastating to the community since there are limited renewable water resources in Arizona. Contamination of a water site could be propagated to downstream areas for years as monsoon rains wash chemicals into the ground water and daily household water supply systems. Contamination of agricultural crops and livestock could also create severe safety issues for the state's food supply. In some cases, long-term contamination of land areas can result in the declaration of a superfund site and invocation of extraordinary clean-up measures. Dry contaminated soil could easily become airborne during the hot and gusty thunderstorm winds, causing people and animals to breathe in toxins which could present serious medical problems in the future.

### **Economic/Financial Condition of Jurisdiction**

Recovery and clean-up costs associated with agriculture contamination, Superfund sites, law suits, and long-term medical issues resulting from hazardous materials incidents can easily lead to financial stress for the State of Arizona. The extent of the hardship will depend on the severity of the hazardous materials incident and areas affected. For instance, a serious release of Chlorine Gas from any rail car traveling through a metropolitan area could create a deadly plume, which, if weather conditions allowed, could kill and seriously injure hundreds of people. This is evident in the proximity of certain chemical manufacture facilities located near schools and highly populated residential and business areas. A serious release could easily have a financial impact on the facility and its employees, the surrounding community and businesses, and the legal fallout from such an event.

### **Public Confidence in Jurisdiction's Governance**

As the public understands most natural hazards, it does not accept the effects of a man-made hazard and usually move swiftly to find someone or some government organization to blame. Knowing this, swift response, proper regulatory action and reporting, and accurate planning are essential to successfully managing hazardous materials incident. As proven in past hazardous materials incidents, these can be very devastating to the regulatory agency and even more devastating to the public. Effective and swift agency response and recovery assistance are key to maintaining the public's confidence, and key government personnel may be held responsible for the success or failure to protect the public from such an event.

### **Cascading/Secondary Impacts**

Long-term disease and lingering health issues can be considered as secondary impacts. Incidents involving explosion or fires have the potential to trigger wildfires.

## RESOURCES

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US Coast Guard, National Response Center, <http://nrc.uscg.mil/Default.aspx>

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## INFECTIOUS DISEASE

An infectious disease is defined as a clinically evident disease resulting from the presence of pathogenic microbial agents. Infectious diseases are a major threat around the world, killing millions globally each year. Fears of pandemic have risen in recent years as our globalized economy and growing population fosters large scale international travel and trade. Also, growing populations, and higher population densities, increase vulnerability to infectious disease as it can travel more quickly and create difficulty in preventing the spread of infection.

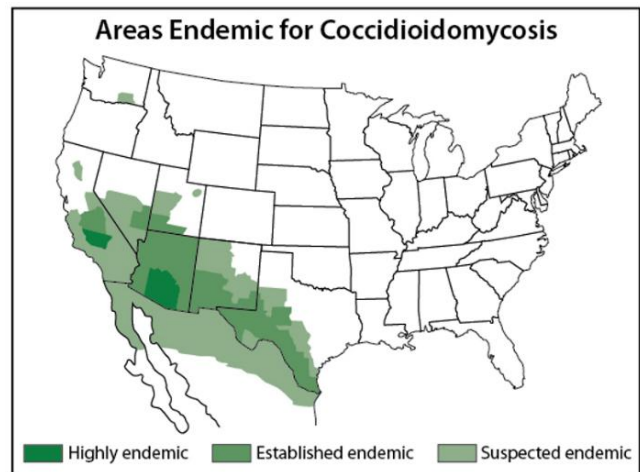
Three terms are commonly used to classify disease impacts: endemic, epidemic, and pandemic. An endemic is present at all times at a low frequency (chicken pox in the United States). An epidemic is a sudden severe outbreak of disease (the bubonic plague during medieval times) and a pandemic is an epidemic that becomes very widespread and affects a whole region, a continent, or the world (e.g., 1957 flu pandemic).



### Endemic Diseases

Pathogens that are constantly present or are usually prevalent in a population within a geographic area are considered endemic. Endemic pathogens to Arizona include:

- Hantavirus Infection
- Plague
- Psittacosis
- Tularemia
- West Nile Virus
- Coccidioidomycosis (Valley Fever)
- Legionellosis (several serogroups)
- Primary Amebic Meningoencephalitis (PAM)
- Rocky Mountain Spotted Fever (RMSF)



Map of areas endemic for Valley Fever (Coccidioidomycosis)  
Source: CDC. Online at: <https://www.cdc.gov/fungal/diseases/coccidioidomycosis/causes.html>

### Modes of Transmission

Transmission of an infectious disease may occur through direct or indirect contact as described below:

#### Direct Transmission

Direct transmission is when an infection spreads through skin-to-skin contact, kissing, or sexual intercourse with an infected individual; or contact with soil/vegetation that harbors

infectious organisms. Direct transmission also includes droplet spread which refers to the spray produced by sneezing, coughing, or even talking.

### **Indirect Transmission**

Indirect transmission is when an infection is spreads via air particles, vehicles (inanimate objects), or vectors (animate intermediaries). Airborne transmission occurs when pathogens are carried through the air by dust or droplet nuclei. Vehicles that may transmit pathogens include food, water, blood, and fomites. Vector transmission occurs when mosquitoes, fleas, ticks, etc., carry pathogens from a host, or reservoir, to an uninfected individual.

## **Disease Categories**

The list of nationally notifiable diseases is revised periodically. Public health officials at state health departments and the Center for Disease Control and Prevention (CDC) collaborate to determine which diseases should be nationally notifiable; the Council of State and Territorial Epidemiologists, with input from the CDC, makes recommendations annually for changes to the list. In Arizona, reporting of nationally notifiable diseases to the CDC is mandated by state legislation and regulations.<sup>16</sup>

The CDC has categorized bioterrorism agents and diseases of concern into three groups which are below:

### **Category A**

High priority agents that pose a risk to national security (Anthrax, Botulism, Plague, Smallpox, Tularemia, Viral Hemorrhagic Fevers):

- Can be easily disseminated or transmitted from person to person;
- Result in high mortality rates and have the potential for major public health impact;
- Might cause public panic and social disruption; and
- Require special action for public health preparedness.

### **Category B**

Second highest priority agents (Brucellosis, Epsilon Toxin, Food Safety Threats, Glanders, Melioidosis, Psittacosis, Q Fever, Ricin Toxin, Staphylococcal Enterotoxin B, Typhus Fever, Viral Encephalitis, Water Safety Threats):

- Are moderately easy to disseminate;
- Result in moderate morbidity rates and low mortality rates; and
- Require specific enhancements of CDC's diagnostic capacity and enhanced disease surveillance.

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<sup>16</sup> Arizona Administrative Code, Chapter 9. Online at: <https://www.azsos.gov/rules/arizona-administrative-code#ID9>



## Category C

Third highest priority agents include emerging pathogens that could be engineered for mass dissemination in the future (Nipha Virus, Hanta Virus, other emerging diseases):

- Availability;
- Ease of production and dissemination; and
- Potential for high morbidity rates and major health impact.

When the CDC is notified or identifies an emerging threat, they will notify and coordinate with the Arizona Department of Health Services (ADHS).

The Bureau of Epidemiology and Disease Control Services collects, analyzes, and distributes infectious disease data to internal programs, public health stakeholders, and counties to monitor public health and assist in the prevention and containment of infectious disease. When notified by the CDC or when ADHS identifies an emerging threat, ADHS will notify and coordinate with the county health departments.

Investigations into the source of an outbreak can depend on the etiology involved (viral, bacterial, parasitic or chemical), the mode of transmission (foodborne, waterborne, environmental, person-to-person), or the outbreak setting (restaurant, hospital or assisted living facility, school or community). Most infectious disease outbreaks can be classified into the following categories tracked by ADHS:

- Foodborne or Waterborne Outbreaks
- Vectorborne or Zoonotic Disease Outbreaks
- Respiratory or Influenza-Like Illness Outbreaks
- Vaccine Preventable Disease Outbreaks
- Healthcare-associated Infection Outbreaks

## HISTORY

Historical records indicate that Arizona has had numerous food-borne, waterborne, environmental, and person-to-person outbreaks harming and killing people and animals. A total of 181,787 confirmed or probable cases of infectious diseases (excluding sexually-transmitted diseases, tuberculosis, hepatitis C, and HIV) have been reported from 2008-2013. Of these, 41% (74,916 cases) were influenza or RSV cases, 34% (62,142 cases) were coccidioidomycosis cases and 9% (17,114 cases) were cases of enteric diseases. The remaining 16% of the cases (27,615 cases) are divided among invasive diseases, hepatitides, other diseases, vaccine-preventable diseases and vector-borne and zoonotic diseases. The morbidities included in each category are summarized in Table 7 below (ADHS, 2015a).

The following are notable infectious disease outbreaks in Arizona, documented by ADHS:

- August 8, 2016 – ADHS announced the end to a three-month measles outbreak that involved 22 confirmed cases that originated in a private detention facility in Eloy, Arizona.
- July 2015 to February 2016 – An outbreak of 140 confirmed cases of Salmonella serotype Poona infection from garden variety cucumbers imported from Mexico caused 44 hospitalizations and six Arizonan deaths.

- June 19, 2013 - After consuming frozen berries, 110 people were confirmed to have become ill from Hepatitis A. Fifteen of the infections were Arizona residents.
- 2009 – Present - The H1N1 pandemic virus strain first appeared in Arizona in 2009 and continues through the present. For the period of April 2009 to May 2010, ADHS registered over 8,700 confirmed cases with 1,409 hospitalizations and 152 deaths. There was a total of 2,506 confirmed cases for the period of 2010-2016.
- 2002 – Present - Arizona experienced two major outbreaks of the Norwalk-like virus (Norovirus). Norovirus continues to be a frequent cause of illness in Arizona with 36 outbreaks in 2015 alone.
- 1993 – 2016 - There have been 75 confirmed Hantavirus cases in Arizona since 1993, 36% of all cases result in death.
  - Hantavirus killed 11 people in the Navajo Nation (CNN, October 15, 1995).
  - June 7, 2013 - Coconino County Public Health Services District officials confirmed that a Flagstaff-area woman died from complications of Hantavirus.

## PROBABILITY/EXTENT

The probability and magnitude of infectious disease is difficult to evaluate due to the wide variation in disease characteristics, such as the reproduction number, virulence, morbidity and mortality, detection and response time, and the availability of vaccines and other forms of prevention. There is growing concern, however, about emerging infectious diseases due to new and more resistant strains of pathogens, also called, “Super Bugs,” and viral reassortments/recombination. The probability of a serious outbreak goes up as new resilient pathogens are identified.

Infectious diseases have the potential to affect any form of life anywhere in the state and some that were thought to have been eradicated have re-emerged. New strains of infectious diseases, such as the flu, present seasonal threats to the populace and require continuous monitoring. Widespread epidemics are almost non-existent in the United States, but if an epidemic event were to occur, deaths could be in the many hundreds of thousands across the nation.

Historically, events have occurred in the farming and agricultural communities that cause great concern amongst responding governmental agencies. Due to these events, and the fact that Arizona shares an international trade border with Mexico, the probability of an infectious disease impacting livestock and crops is high.

An average of 30,000 confirmed and probable cases of infectious diseases, across all categories included in Table 7, have been reported each year from 2008-2013, with a maximum of 42,387 cases in 2009 and a minimum of 19,968 cases in 2008. This corresponds to an average rate of 377 cases per 100,000 populations per year (ADHS, 2015a). ADHS tracks infectious disease outbreaks, and according to ADHS officials (2015b), the large majority of outbreaks tend to result in some form of gastrointestinal illness. In 2015, over 137 outbreaks of gastrointestinal illness were reported to ADHS and were caused by various infections such as norovirus, E.coli, salmonella, and listeria. ADHS studies also show that the mode of transmission for most (72% in 2014) outbreaks is via person-to-person contact (ADHS, 2014).

According to state officials (Komatsu, 2018), ADHS deals with routine outbreaks of various diseases including plague, brucellosis, tularemia, Q fever (all select agents) as well as hantavirus pulmonary syndrome and severe influenza seasons. These instances typically never rise to the level of a local declaration of emergency. Given the state's population distribution, endemic disease, geography and climate, and healthcare system infrastructure, an estimation of the diseases that would likely impact Arizona on a scale that would result in a local, county, or statewide declaration of emergency include:

- Bioterrorism vent using one of the select agents. Additionally, with bioterrorism agents – weaponized strains may be more difficult to mitigate if they have enhanced infectivity, virulence, and drug resistance than those found in nature.
- Pandemic influenza.
- High impact animal disease such as:
  - Foot and Mouth Disease (FMD virus)
  - High pathogenic Avian Influenza
  - Tuberculosis
  - Q Fever (coxiella burnetii)
  - Newcastle Disease (Paramyxovirus 1)

**Table 7: Infectious Disease Categories and Morbidities**

Disease Category	Reportable Morbidities
<b>Coccidioidomycosis</b>	Coccidioidomycosis
<b>Enteric Diseases</b>	Amebiasis, botulism, infant botulism, campylobacteriosis, cryptosporidiosis, cyclospora infection, cysticercosis, <i>E. coli</i> enterohemorrhagic, giardiasis, hemolytic uremic syndrome, listeriosis, salmonellosis, shigellosis, typhoid fever, <i>Vibrio</i> infection, yersiniosis
<b>Flu and RSV</b>	Influenza virus, influenza with mortality in a child, respiratory syncytial virus (RSV)
<b>Invasive Diseases</b>	Invasive methicillin-resistant <i>Staphylococcus aureus</i> (MRSA), invasive streptococcal group A, invasive streptococcal group B (in children <90 days of age), invasive <i>Streptococcus pneumoniae</i> , vancomycin-intermediate <i>Staphylococcus aureus</i> (VISA), vancomycin-resistant <i>Staphylococcus aureus</i> (VRSA), vancomycin-resistant <i>Staphylococcus epidermidis</i> (VRSE)
<b>Hepatitides</b>	Hepatitis A, hepatitis B acute, hepatitis B chronic, hepatitis B perinatal, hepatitis D
<b>Other</b>	Basidiobolomycosis, blastomycosis, Creutzfeldt-Jakob disease, emerging or exotic disease, parasitic encephalitis, Hansen's disease, Kawasaki syndrome, legionellosis, Reye syndrome, toxic shock syndrome, viral encephalitis
<b>Vaccine preventable diseases (VPD)</b>	Invasive <i>Haemophilus influenzae</i> , measles, invasive meningococcal disease, mumps, pertussis, poliomyelitis, rubella, smallpox, tetanus, vaccinia-related event, yellow fever
<b>Vector-borne and zoonotic diseases</b>	
<b>Mosquito-borne Diseases</b>	Dengue, Eastern Equine encephalitis virus, Japanese encephalitis virus, malaria, St. Louis encephalitis virus, Venezuelan equine encephalitis virus, West Nile virus and Western equine encephalitis virus
<b>Tick-borne Diseases</b>	Babesiosis, Colorado tick fever, ehrlichiosis or anaplasmosis, Lyme disease, relapsing fever, Rocky Mountain spotted fever and typhus fever
<b>Flea-borne Diseases</b>	Plague
<b>Zoonotic Diseases</b>	Brucellosis, hantavirus infection, hemorrhagic fever, leptospirosis, melioidosis or glanders, psittacosis, rabies (human cases), taeniasis, trichinosis, and tularemia

Source: ADHS

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## **WARNING TIME**

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There is generally no warning time for the initiation of an infectious disease outbreak. However, once an outbreak begins, there is opportunity to warn the public about the occurrence and provide health-care guidance for preventative measures.

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## **FUTURE CONDITIONS**

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### **Climate Considerations**

Changes in future climate conditions may have an impact on certain types of infectious disease, or possibly have an indirect effect. For example, increased temperatures and intensities of Arizona's summer temperatures and monsoon thunderstorms may increase the incidents of Valley Fever by creating more severe dust storms. Increased drought conditions may force the import of more food from outside the drought region, which may increase the exposure to new or foreign pathogens.

### **Changes in Development**

The primary impacts associated with development changes is the increase in population densities that accompany the growth. The higher densities of people increase both the risk of exposure and the opportunity for transmission.

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## **VULNERABILITY ASSESSMENT**

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The entire state is vulnerable to infectious diseases, however given the statistical dominance of person-to-person transmission of most infectious diseases, it is estimated that higher population density areas are inherently at a higher risk of exposure. Additionally, certain airports within the state have large populations of passengers moving in and out of the airport, both domestically and internationally, with great potential to quickly spread infectious diseases into and out of the state. Accordingly, vulnerability for each planning region is presented by the average population density in persons per acre, airport locations and departing international passenger volume for 2011-2016 (USDOT), and total communicable disease totals for the five-year period of 2013-2017 (ADHS).

The population densities were derived using the US Census Bureau's American Community Survey (ACS) data for 2015, as compiled at the Census Tract level. GIS tools were used to develop persons per acre densities for each Census Tract area, with the densest upper one-third of the Census Tracts being considered the as the highest risk areas.

The volume of international passengers was estimated using US Department of Transportation aviation data for the number of passengers departing a US airport for an international destination for the 2011-2016 travel years (USDOT, 2017).

## North Region

The North Region vulnerability is considered the least vulnerable to infectious disease, primarily since the region has the least population density, very little international air travel, and the lowest number of communicable disease cases.

### State-Owned CFI Exposure and Loss Estimates

All 1,988 state-owned facilities representing \$2.4 billion in replacement value are considered equally exposed to infectious diseases. No losses are estimated.

### Vulnerable Population Groups

The entire 2015 estimated population of 772,157 people are considered as exposed to infectious diseases, with approximately 202,798, or 26.26% of the region-total population, being located within the upper one-third densest areas of the state. The exposed sub-group population totals include 177,450 persons (23.0% of region total) under 18-years of age, 158,170 persons (20.5% of region total) older than 65, 163,483 persons (21.2% of region total) living at or below poverty level, and an LEP population of 56,625 (7.3% of region total). Estimates for each of these population sectors located within upper one-third densest areas.

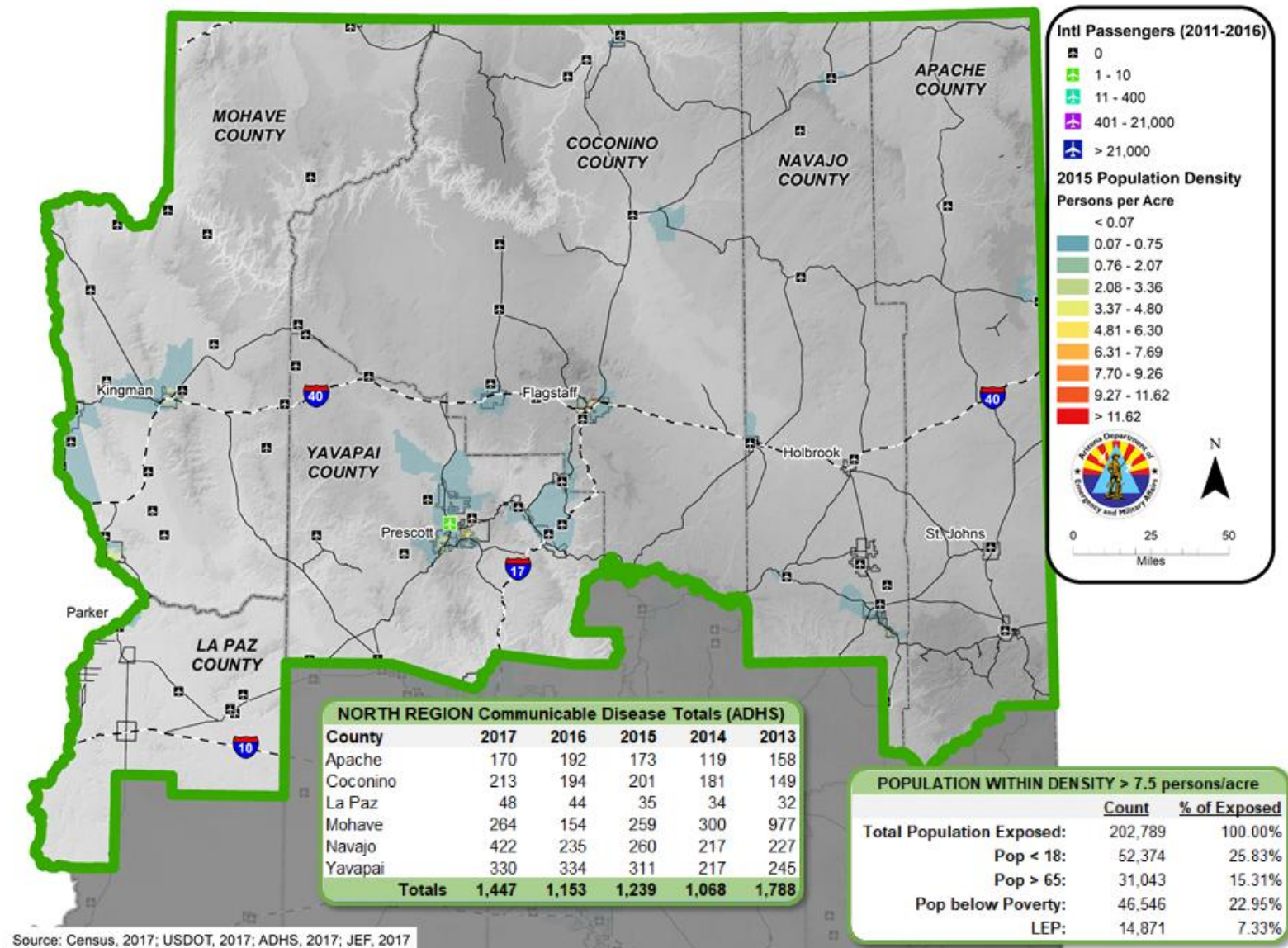
### Local Jurisdiction Vulnerability

Only Mohave County included infectious diseases in their mitigation plan risk assessment. Conclusions of the vulnerability analyses are similar to what is presented in this Plan and no local critical facility losses were estimated.

### Specific Areas of Concern

According to ADHS (2015b), Coconino (n=4), La Paz (n=5), and Navajo (n=3) have some of the highest incident rates of outbreak (“n” persons per 100,000) in the state for reporting year 2015. For the five-year period of 2008-2013, ADHS also notes (ADHS, 2015b) that the North Region counties have some of the highest incident rates for campylobacteriosis, cryptosporidiosis, invasive *Streptococcus pneumoniae*, streptococcal group A, pertussis, hantavirus pulmonary syndrome, and Rocky Mountain spotted fever. The North Region is home to the Laughlin-Bullhead City International Airport (IFP), which has the second largest volume of international traffic of all the airports in Arizona. According to the USDOT (2017), there have been approximately 37,000 passengers that departed from IFP to international destinations during the seven-year period of 2011-2016. The portion of those departures that are US citizens will eventually return home to the United States. The rest are foreign visitors that are now leaving the United States. In either case, there is a significant risk of exposure to international diseases and introduction of new foreign strains to Arizona.



**Map 26: Infectious Disease Vulnerability for North Region**

## Central Region

The Central Region is considered the most vulnerable to infectious disease, primarily since the regions has the most population density, substantial international air travel volume, and the highest number of communicable disease cases.

### State-Owned CFI Exposure and Loss Estimates

All 3,464 state-owned facilities representing \$9 billion in replacement value are considered equally exposed to infectious diseases. No losses are estimated.

### Vulnerable Population Groups

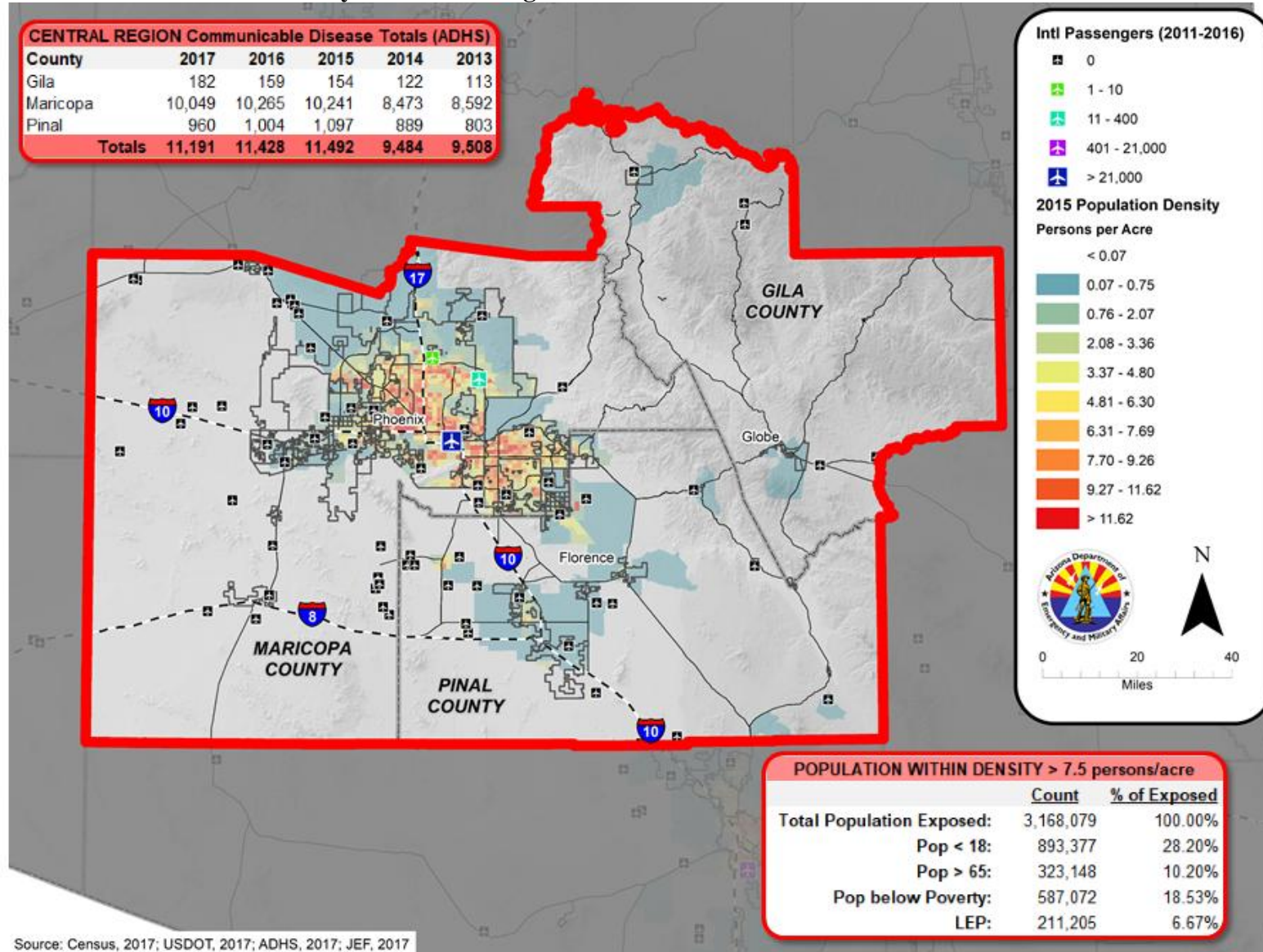
The entire 2015 estimated population of 4,604,414 people are considered as exposed to infectious diseases, with approximately 3,168,079, or 68.81% of the region-total population, being located within the upper one-third densest areas of the state. The exposed sub-group populations include 1,216,158 persons (26.4% of region total) under 18-years of age, 618,612 (13.4% of region total) persons older than 65, 748,257 persons (16.3% of region total) living at or below poverty level, and an LEP population of 306,961 (6.7% of region total). Estimates for each of these population sectors located within upper one-third densest areas.

### Local Jurisdiction Vulnerability

Only Maricopa County addressed infectious diseases in their mitigation plan risk assessment. Conclusions of the vulnerability analysis are similar to what is presented in this Plan and no local critical facility losses were estimated.

### Specific Areas of Concern

For the five-year period of 2008-2013, ADHS notes (ADHS, 2015b) that the Central Region counties have some of the highest incident rates for Valley Fever (coccidioidomycosis) campylobacteriosis, MRSA, streptococcal group A, pertussis, West Nile virus, and Rocky Mountain spotted fever (mainly Gila County). The Central Region is home to Sky Harbor International Airport (PHX), which is one of the largest airports in the country. According to the USDOT (2017), there have been approximately 13.3 million passengers that have departed from Sky Harbor to international destinations during the seven-year period of 2011-2016. The portion of those departures that are US citizens will eventually return home to the United States. The rest are foreign visitors that are now leaving the United States. In either case, there is a significant risk of exposure to international diseases and introduction of new foreign strains to Arizona.

**Map 27: Infectious Disease Vulnerability for Central Region**



## South Region

The South Region is considered the second-most vulnerable to infectious disease, primarily since the region has the second-highest population density, moderate international air travel volume, international foot traffic from Mexico, and the second-highest number of communicable disease cases. Influences of the international border crossings are also a factor.

### State-Owned CFI Exposure and Loss Estimates

All 1,505 state-owned facilities representing \$5.2 billion in replacement value are considered equally exposed to infectious diseases. No losses are estimated.

### Vulnerable Population Groups

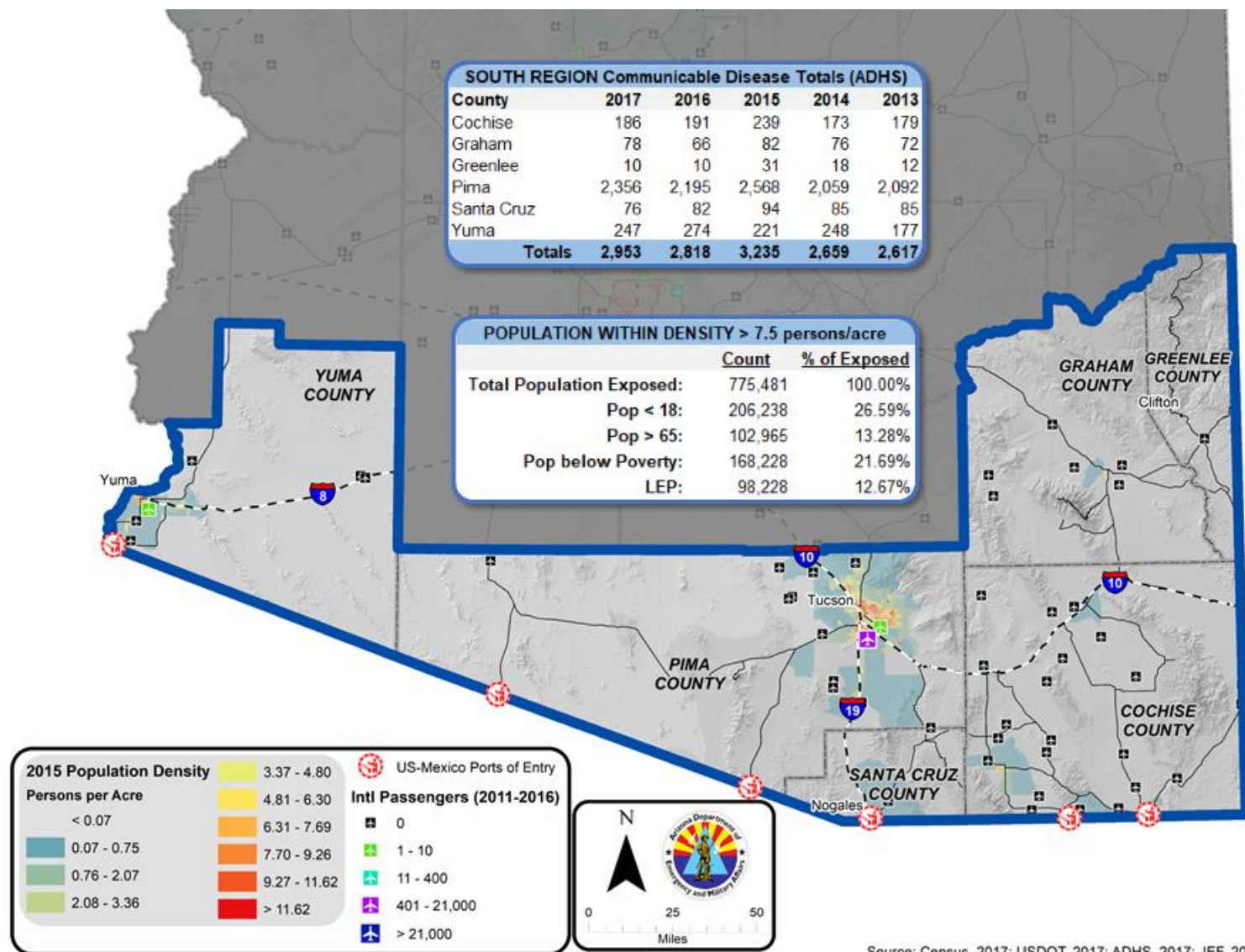
The entire 2015 estimated population of 1,458,367 people are considered as exposed to infectious diseases, with approximately 775,481, or 53.17% of the region-total population, being located within the upper one-third densest areas of the state. The exposed sub-group populations include 354,191 persons (24.3% of region total) under 18-years of age, 242,700 (16.6% of region total) persons older than 65, 268,372 persons (18.4% of region total) living at or below poverty level, and an LEP population of 306,961 (6.7% of region total). Estimates for each of these population sectors located within upper one-third densest areas.

### Local Jurisdiction Vulnerability

None of the local counties in the South Region included infectious disease in their mitigation plan risk assessments.

### Specific Areas of Concern

According to ADHS (2015b), Graham (n=5) and Greenlee (n=9) Counties have some of the highest incident rates of outbreak (“n” persons per 100,000) in the state for reporting year 2015. For the five-year period of 2008-2013, ADHS notes (ADHS, 2015b) that the South Region counties have some of the highest incident rates for Valley Fever (coccidioidomycosis) campylobacteriosis, MRSA, West Nile virus, and legionellosis. The South Region is home to Tucson International Airport (TUS), which has the third largest volume of international traffic of all the airports in Arizona. According to the USDOT (2017), there have been approximately 21,000 passengers departing from TUS to international destinations during the seven-year period of 2011-2016. The portion of those departures that are US citizens will eventually return home to the United States. The rest are foreign visitors that are now leaving the United States. In either case, there is a significant risk of exposure to international diseases and introduction of new foreign strains to Arizona. Additionally, the South Region borders the country of Mexico where there is limited monitoring, and unaccounted immigration can lead to an increased vulnerability.



Map 28: Infectious Disease Vulnerability for South Region



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## POTENTIAL CONSEQUENCES AND IMPACTS

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### Public

Public response to a disease outbreak or pandemic can vary from mild to severe. Panic is a normal reaction to extraordinary disease outbreaks and pandemics. The probability of a serious outbreak of disease to overload medical resources is high, so protective measures, including: education, possible isolation, quarantine, travel deferment, closure of school and universities, closure of government functions, suspension large public gatherings, and closure of public travel assets, will all impact the general public.

Diseases affecting animals and plants, particularly livestock and agricultural products, are also of major concern, since those impacts will translate directly into the supply and quality of human food supplies, as well as potential economic consequences, and impact on foreign trade.

### Property/Facilities/Infrastructure

Negative impacts related to the potential for physical damage to property, facilities, and state-owned infrastructure is not a factor; however, contamination due to infectious disease exposure to water and food supplies could result in significant losses.

### Responders

Responders, recovery personnel and volunteers would be quickly overwhelmed if a serious outbreak of disease were to occur in Arizona. Due to population density in the major metropolitan areas, the capabilities to quickly respond, identify and control such outbreaks are crucial. Potential dangers include the rapid onset of disease that moves faster than the response can actively follow, number of responders who could become unknowingly infected during initial onset causing loss of essential assets and risk of new introduction or spread of infectious diseases.

The Department of Agriculture and Game and Fish Department are primarily concerned with plant, livestock and wild animal diseases and infections. The agencies are concerned with animal-to-animal diseases, as well as diseases transmitted from animals or arthropod vectors to humans. The scope and severity of an infectious outbreak could easily over task these departments causing requests for additional resources to be called from outside Arizona.

### Continuity of Operations/Delivery of Services

Operational impacts could be catastrophic depending on the type, severity and spread of infectious diseases. This is particularly true of those capable of disrupting the human or animal food chain. During a pandemic, public health professionals may quarantine or recommend limited operation of facilities with contamination from an infectious disease. All non-essential infrastructure components could easily be affected as people would choose to stay home rather than risk possible infection. Additionally, facilities directly involved in the line of infection could be shut down for extended periods of time costing time and money. A regional pandemic could significantly hinder or even cripple a facility's ability to function and provide service.

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## **Environment/Cultural**

True direct environmental impacts of pandemics and infectious disease threats are negligible, or at worst, short-lived. Culturally, the greatest impacts would manifest in the closure of cultural centers due to sickness in personnel to run and operate the facilities. Social disruption may be greatest when rates of absenteeism impair essential services, such as power, transportation, and communications that serve the cultural needs. Culture could be significantly impacted if an outbreak were to occur within a population group that has strong cultural ties to a geographical location, or if an outbreak spread through a close knit community that has strong social ties.

## **Economic/Financial Condition of Jurisdiction**

Research conducted by Meltzer et al. (1999) on the economic costs associated with pandemic influenza in the United States, estimates the costs of an infectious disease outbreak with a nationwide case attack rate of 15% is between \$71.3 and \$166.5 billion (in 1995 dollars). These costs include lost productivity, direct medical costs, and death associated costs. Converting to 2017 dollars yields figures in the range of \$111.7 and \$260.7 billion dollars, which translate to a unit cost range per infected person of \$345 - \$805. Assuming a statewide infection rate of 15%, the total economic cost range could be \$35.4 to \$82.5 million. Portions of this would be covered by health insurance, but non-covered expenses would likely fall to the local and state agencies and could result in a significant impact. This would be particularly impacting to small, rural areas with significant low-income populations.

The potential for high rates of illness and worker absenteeism within the business and trade community, could lead to significant social and economic disruption. On a national scale, Molinari et al. (2007) estimated that a severe influenza pandemic could cost the US economy more than \$16.4 billion in lost earnings.

Infectious disease or pandemics that affect the farming community within the state would have serious negative effects on the economy. The loss of human and animal life, the loss of tax revenue, and the loss of business at these facilities and their supporting infrastructure, would inevitably be shut down until the disease is identified, controlled and cleaned up. The additional problem associated with agriculture is time. Since crops are seasonal, the turn-around period could be lengthy if the product is a victim of infestation. This scenario could possibly cause a ripple effect in the supporting agriculture infrastructure causing a spike in prices and financial strain on those involved in all aspects of production, distribution and supply or agricultural products.

## **Public Confidence in Jurisdiction's Governance**

The ability of public agencies and medical services to quickly act during an outbreak of disease is in direct correlation to public confidence in jurisdictional governance. Failure of these entities to act in a reasonable manner warranted by the magnitude and severity as seen through the public eye, will drastically reduce the public's confidence in the government's ability to accurately control an outbreak. The magnitude of an outbreak can have severe psychological impacts the population. The media, if not monitored, can cause widespread panic resulting in a severe overload of resources and extreme financial costs to government and the public. Depending on the depth of public perceptions of safety, or lack of, public reaction could span from compliance to lawlessness.

## Cascading/Secondary Impacts

There are no significant cascading or secondary impacts associated with infectious diseases other than the potential for loss of long-term staff and employees with strong institutional knowledge, expertise and experience, effectively hindering an agency or company's ability to recover from a pandemic or epidemic.

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## LANDSLIDE

Landslide is the general term used to describe the downslope movements of soil, rock and organic material under the influence of gravity. Other terms, such as mass movement or slope failure, are technically more accurate but are not as commonly used.

Landslides result from disturbances in the natural stability of a slope. Frequently, they accompany heavy rains, earthquakes, or volcanic eruptions, and are principally associated with mountainous areas, although they can occur in areas of low relief, as well.

Common landslide triggers include heavy rain, rapid snow melt, earthquakes, volcanic eruptions, and freeze and thaw cycles.

Landslides are classified by the type of movement and the type of material moving. Landslide types documented in Arizona are rotational and translational slides, rock falls and/or topples, and debris flows. Table 8 and Figure 10 combine to provide a matrix description and illustration of landslide types.



Landslide damage to US 89 at Echo Cliffs near Page, AZ  
Source: [AzDEMA](#), 2013

**Table 8: Landslide Types**

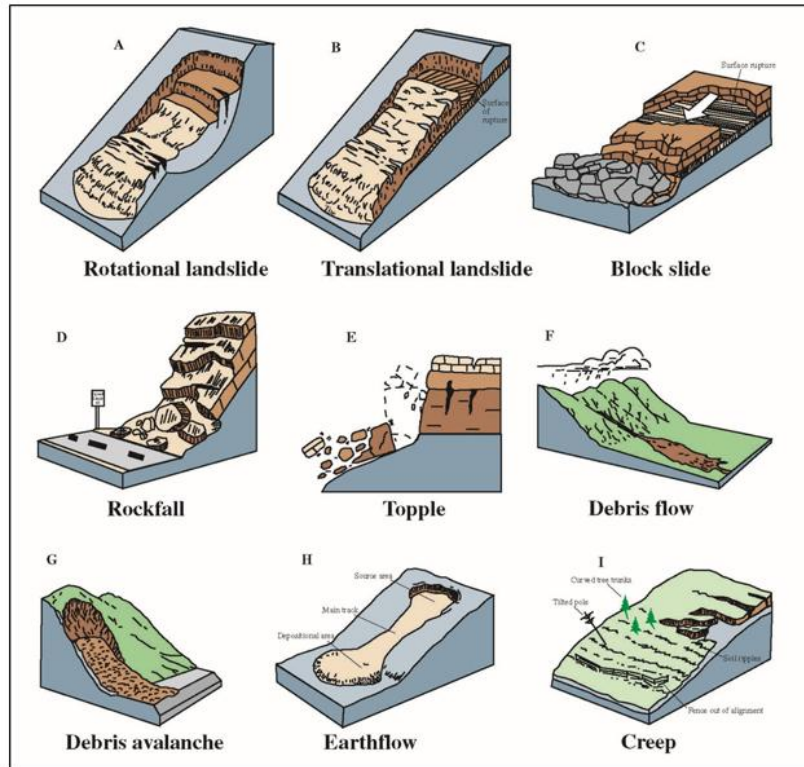
Type of Movement	Type of Material		
		Engineering Soils	
	Bedrock	Predominantly Coarse	Predominately Fine
Slides (Rotational or Translational)	Rock slide or Toreva-block	Debris slide	Earth slide
Falls	Rock fall	Debris fall	Earth fall
Topples	Rock topple	Debris topple	Earth topple
Flows	Rock flow	Debris flow	Earth flow (fast) Earth creep (slow)
Lateral Spreads	Rock spread	Debris spread	Earth spread
Complex	Combination of two or more principal types of movement		
Source: Youberg, et.al., 2018			

According to recent work performed by the Arizona Geological Survey (Youberg, et.al., 2018), the three most common movement types in Arizona are slides, falls/topples, and flows.

## Slides

Slides are downslope movements of soil or rock along a surface of rupture, also sometimes called a rupture plane. The sliding mass may move beyond the rupture plane to deposit on original ground surface, which is called the surface of separation. The shape of the rupture plane reflects the type of movement: rotational or translational. Slides can be found across the state and have been the cause of significant damages.

**Figure 10: Landslide Types**



Block diagram of the different types of mass movements, generally termed "landslides"  
Source: Figure 1 from Youberg, et al., 2018

## Falls and Topples

Downslope movement of soil and/or rock that detaches along a surface with little or no shear displacement and descends by falling through the air or bouncing and rolling on lower slopes. A topple begins by the forward rotation of rock or a soil mass out of a slope, pivoting about a point or axis. Topples may lead to falls or slides depending on the rock or soil mass and the geometry of the slope. Rock falls and topples are common in Arizona along steeper sections of slopes with cliff-forming strata. Oak Creek Canyon, Mount Lemmon Hwy, and the Vermillion Cliffs are just a few places where frequent rockfalls or topples occur.

## Flows

Spatially continuous, non-cohesive, downslope movement of soil and/or rock with a behavior more similar to a plastic or viscous fluid. Generally, the structure of the soil or rock mass in a flow is not preserved. Flows velocities can range and often are triggered by slides that transition into flows. Debris flows are rapidly moving, saturated, unsteady, non-uniform, very poorly sorted sediment slurries that form in steep channels and gullies. Debris avalanches are similar to debris flows but form on and travel down open hillslopes instead of in channels. Faster moving



earth flows and slower moving earth creeps can occur on lower gradient slopes and are generally composed of fine-grained material, silt and clay, or very weathered bedrock. Debris flows occur across the state and are currently considered to be the most common landslide type in Arizona.

## HISTORY

There has only been one state disaster declaration for a landslide event. It is noted, however, that several other state and federal declared events included impacts from post-wildfire and flood triggered debris flows. Notable landslides that have occurred in Arizona over the last half-century are listed below:

- February 2013 - A large translational landslide in northern Arizona, about 23 miles south of Page, destroyed a significant section of US 89A. Costs to establish the “Page Detour” and repair the highway were approximately \$60 million (Youberg, et.al., 2018).
- January 2010 – A large mudslide covered State Hwy 87 about two miles south of Sunflower in the same location a previous slide had heavily damaged the road in 2008 (see below). The slide caused a closure of the four-lane roadway for several days. The mudslide was precipitated by major winter rainfall in the area during the January 2010 flooding that ultimately resulted in the FEMA-1888-DR presidential disaster declaration.
- March 2008 - A rotational slump landslide buckled pavement on State Hwy 87 between Sunflower and Rye, in the Slate Creek area. The southbound lanes of the four-lane divided highway were most severely affected. The road was closed for over a week and the southbound lanes were closed for several months while repairs were made (AZGS, 2008). Repair costs were estimated to exceed \$18 million and communities like Payson, Strawberry, Pine, Heber-Overgaard, and Forest Lakes were negatively impacted by a significant downturn in tourists and camping travelers (Arizona Republic, 2008).
- July 2006 - Extreme precipitation caused approximately 1,000 debris flows in four mountain ranges in southern Arizona. The cost to repair infrastructure destroyed in Sabino Canyon, near Tucson, was estimated to exceed \$1.5 million. Coronado National Memorial in the southern Huachuca Mountains was temporarily closed due to debris flows and flood damage, and Mount Lemmon Hwy was damaged in several places (AZGS, 2007; Youberg, et.al., 2018).
- December 1995 - A massive landslide blocked the Moenkopi Wash near Tuba City in Coconino County. The landslide deposit created an unstable dam and with the threat of an imminent flash flood impacting downstream communities, a state of emergency was declared (DEMA, March 2003; AZNG, 1997). Tuba City was evacuated until the threat passed and no deaths or injuries were reported.
- The Grand Canyon is also littered with landslides and debris flows of various types and sizes that occasionally dam and alter the river morphology and cause repeated damage to



Sabino Canyon Debris Flow (2006)  
Source: AZGS website

a water supply pipeline at Phantom Ranch, destroyed hiking trails, destroyed vehicles, and threatened lives at Diamond Creek (Griffith, et.al., 2004).

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## PROBABILITY/EXTENT

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The probability of a landslide occurring somewhere in the state in any given year is a near certainty, and the likelihood of an event causing severe damage to infrastructure, or injury or loss of life is highly dependent on its location. The Arizona Geological Survey (AZGS) recently initiated a Landslide Hazards Program to compile and publish the Arizona Statewide Landslide Inventory Database (AzSLID), which constitutes the first comprehensive landslide inventory for the State of Arizona. AZGS researched and compiled all forms of landslides from available maps, reports, and journal articles, and also added unmapped landslides features based on interpretation of aerial imagery and topography. The identified features were compiled into a database and attributed according to failure type, mechanism, and source. AzSLID is a work-in-progress and now contains more than 6,300 landslide features covering approximately 780 square miles of land area across the state. Map 29 presents the current AzSLID database features on a statewide basis and provides context for landslide hazard profile.

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## WARNING TIME

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Most landslides occur without warning and are often triggered by other hazard events such as heavy rain, rapid snow melt, earthquakes, volcanic eruptions, freeze and thaw cycles, and post-wildfire conditions. Indirect warning may occur in the form of indicators pointing to slope weakening before a landslide, however, this is not always the case. These indicators may include sunken road beds, cracked foundations, leaning trees or fences<sup>1</sup>. Impacts of these events in Arizona are often localized and limited in scope.

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## FUTURE CONDITIONS

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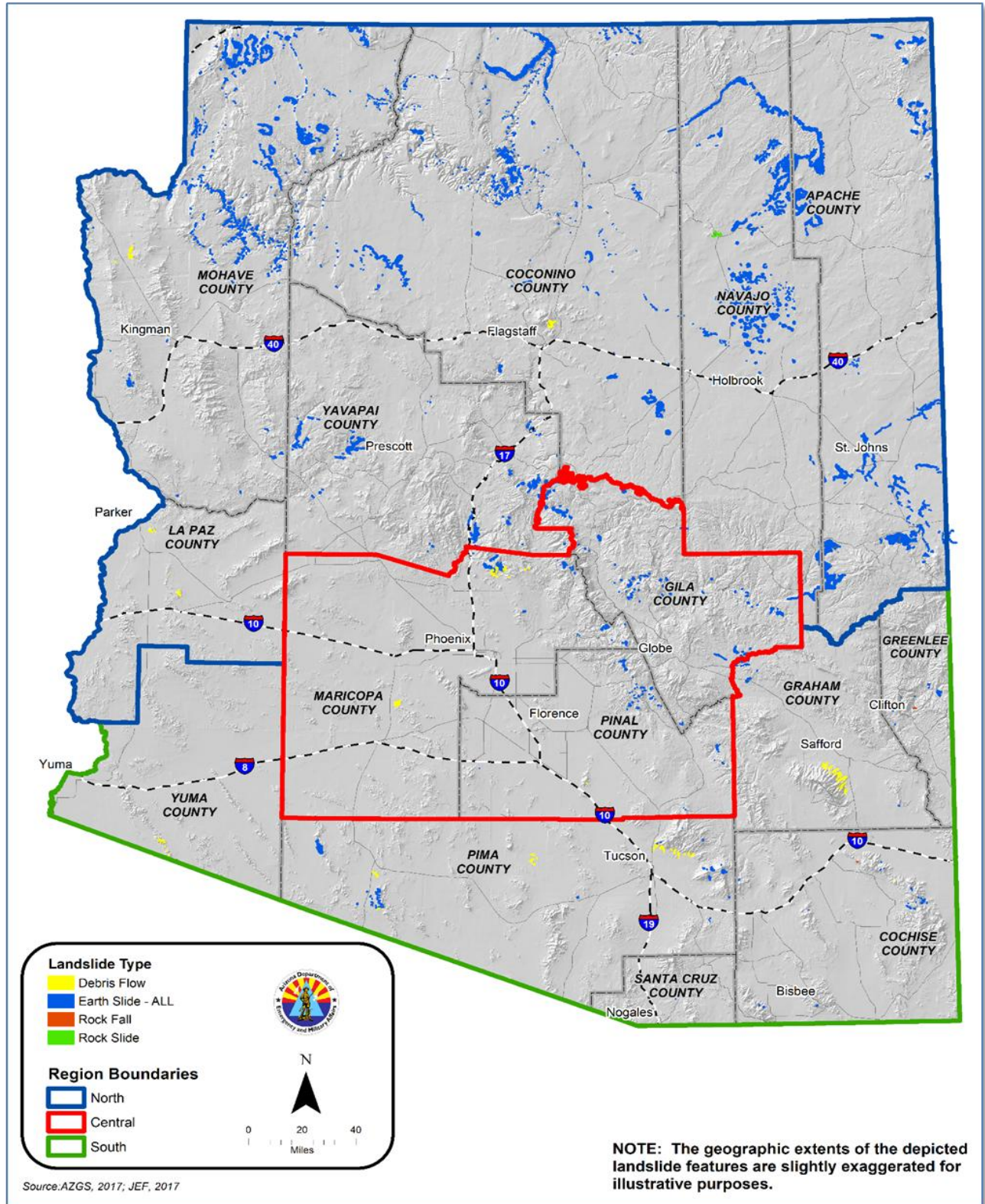
### Climate Considerations

Climate change impacts on the frequency and severity of landslides in Arizona, is better correlated to climate change induced alterations to triggering events such as monsoon thunderstorm intensities, winter freeze and thaw, winter rain and snow events, and vegetation altering changes due to drought and wildfire. Projections of intensifying monsoon thunderstorms, changing winter precipitation patterns and intensities, and a hotter and drier environment leading to deeper droughts and increased wildfires, will all translate to increased landslide activity (Garfin, et.al., 2014) (Luong, et.al., 2015).

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<sup>1</sup> USGS (2017) Landslide Preparedness: Landslide Warning Signs. <https://landslides.usgs.gov/learn/prepare.php>

**Map 29: Landslides Statewide**





## Changes in Development

Development of mountainsides, areas with steep terrains, or areas located at the base of steep mountain slopes, are all at an elevated risk of landslide. Construction of new or widened highway segments through mountainous or steep terrain areas are also have an elevated landslide risk. Housing and roadway/highway development in the aforementioned areas can also increase the probability and risk to the population.

### North Region

The majority of the anticipated growth in the North Region is expected to expand from the existing jurisdictions, such as Sedona and Flagstaff. Hillside development is popular and sometimes necessary in the North Region, as hillside cuts are required for many roadway improvements in the area. Areas of greater slope will also be areas of greatest risk for landslides. Natural erosion on hillsides can also create conditions that may sporadically cause rockfalls that may impact roads and structures in the immediate area.

### Central Region

The most significant development in the Central Region is expected to primarily occur in the Phoenix Metropolitan Area. Gila County experiences landslides in their mountainous areas; however, these areas are not expected to experience significant changes in development. Highway widening projects such as ADOT's recent widening of the Devil's Canyon and the US 60 Oak Flat project between Superior and Miami will create significant cuts through steep canyon walls in an area that already has a history of rock fall activity.



Soldier Canyon debris flow. Small arrows at top of photo show where cobbles and boulders were deposited just upstream of several homes during 2006 event (Figure 9 in reference).  
Source: [Pearthree and Youberg, 2006](#)

### South Region

The Tucson Metropolitan Area is one of the most significant areas for development in the South Region. Growth of development in the surrounding Tucson area mountain ranges and associated foothill regions is expected to continue at a low to moderate pace and will effectively broaden the exposure and risk to landslides and debris flows.

## VULNERABILITY ASSESSMENT

Landslides can result in deaths, injuries, and significant damages to impacted infrastructure and assets. For this Plan, the Planning Team chose to classify the AzSLID identified landslide areas as high hazard areas, with the recognition that landslide hazards exist outside of those identified areas but are currently not identified or mapped. The estimation of potential exposure to the

identified high hazard areas was accomplished by using GIS mapping and analysis tools to intersect the vulnerable population and state-owned facility data with the landslide hazard limits depicted on the map that follows. The GIS analyses revealed that none of the state-owned buildings or structures are located in or within 1,000 feet of the landslide high hazard areas. Many of the state-owned and operated roadways, however, do intersect the mapped landslide areas. There were also small segments of population that were identified to be located within a census block proximity to the high hazard areas. For this vulnerability assessment, two sets of data are presented. The first is the mileage of state-owned and maintained roadways<sup>1</sup> exposed to, or within 1,000 feet of, a currently mapped landslide zone. The second is a summary of resident population sectors located within the landslide zone. Summaries of these results by state planning region are provided below.

## **North Region**

The North Region is the most vulnerable region of the state, primarily due to the population and mileage of highways exposed.

### **State-Owned CFI Exposure and Loss Estimates**

None of the state-owned CFI are located in, or within 1,000 feet of, the identified landslide hazard zones. Approximately 89.3 miles of state-owned roadway is located in or within 1,000 feet of an identified landslide hazard zone, with the longest continuous segment being 6.8 miles and the shortest being less than 100 feet. Approximately 11.4 miles of the exposed roadway is composed of two segments of I-17.

### **Vulnerable Population Groups**

The 2015 estimated total population for the North Region is 772,157 people. Approximately 0.22% of the total population, or 1,666 persons, are located within the high landslide hazard areas.

On average, approximately 7.3% of the North Region population is estimated to have a Limited English Proficiency (LEP). Assuming the percentage is equally applied across the whole region's population, roughly 122 LEP persons (6.7% of 1,666) are estimated to be located within the high landslide hazard areas.

### **Local Jurisdiction Vulnerability**

Yavapai County included landslide in their risk assessment but did not specifically estimate quantitative landslide related losses for locally identified critical and non-critical facilities. The Yavapai County plan did note that historic losses primarily occurred along major roadways with repair and cleanup costs ranging from \$1,500 to \$150,000. Jerome was also identified as an area of elevated risk.

### **Specific Areas of Concern**

As noted in the Yavapai County plan, the Town of Jerome is constructed entirely on the side of a mountain (Cleopatra Hill) and has experienced significant ground movement

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<sup>1</sup> Highways classified as either interstate, UShighway, or state routes.



over the past century, and remains at an elevated risk to ground movement. The AZGS (Youberg, et.al., 2018) has noted that the potential risk of debris flow is greatly underappreciated and warrants further study across the whole state, especially in wildfire prone areas with significant population and infrastructure located at the base of steep slopes such as Williams, Sedona, and the Fort Valley community outside of Flagstaff.

## Central Region

The Central Region is considered the second-most vulnerable region in the state, due to the mileage of highway exposure and the potential economic impacts of closures on the exposed roadways, and primarily State Route 87.

### State-Owned CFI Exposure and Loss Estimates

None of the state-owned CFI are located in, or within 1,000 feet of, the identified landslide hazard zones. Approximately 10.7 miles of state-owned roadway is located in, or within 1,000 feet of, an identified landslide hazard zone, with the longest continuous segment being 2.4 miles and the shortest being less than 600 feet. The majority of exposed roadway (10.4 miles) is composed of segments of SR 87 between Phoenix and Payson.

### Vulnerable Population Groups

The 2015 estimated total population for the Central Region is 4,604,414 people. Approximately 0.001% of the total population, or 48 persons, are located within the high landslide hazard areas.

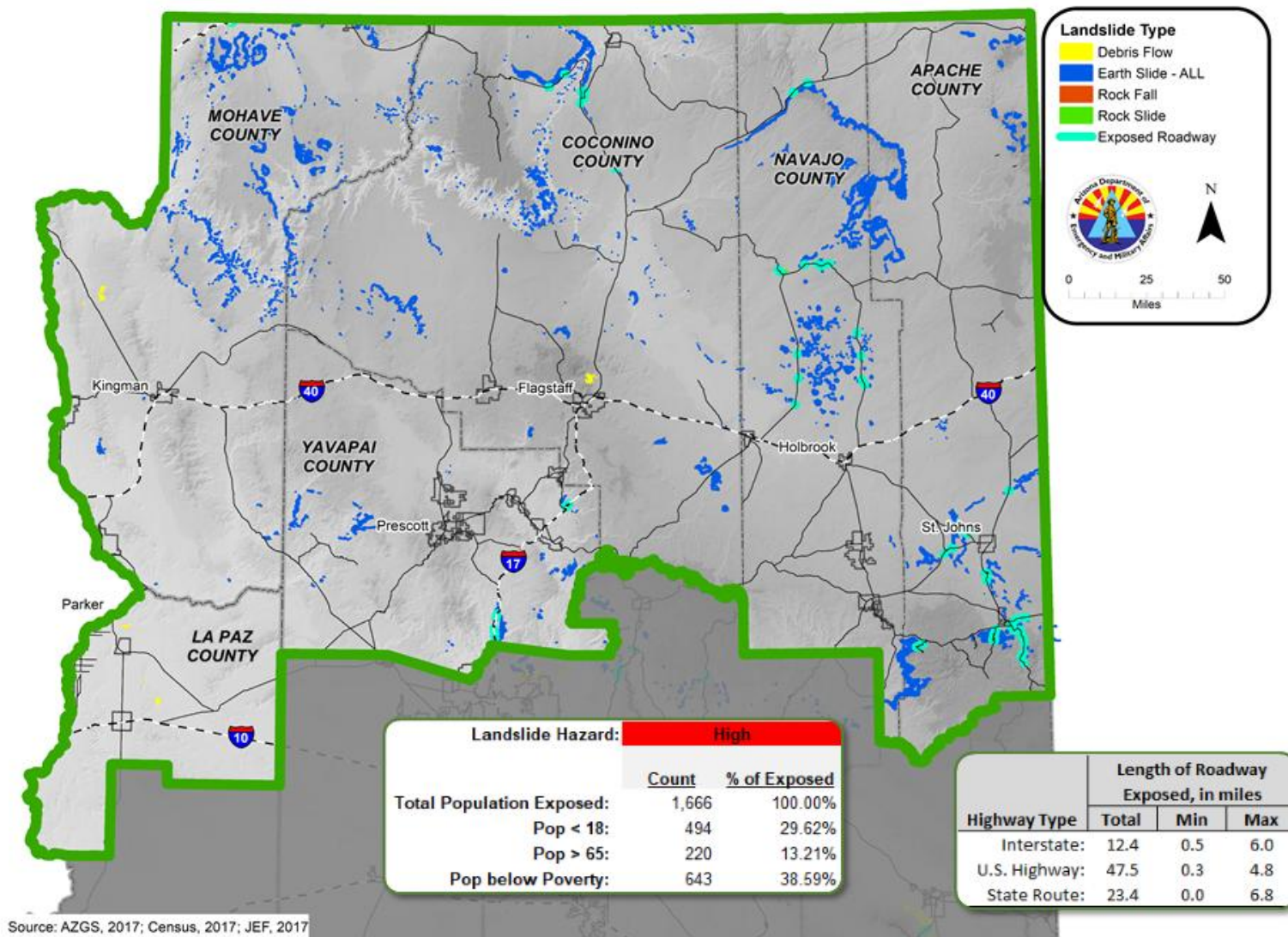
On average, approximately 6.7% of the Central Region population is estimated to have a Limited English Proficiency (LEP). Assuming the percentage is equally applied across the whole region's population, roughly 4 LEP persons (6.7% of 48) are estimated to be located within the high landslide hazard areas.

### Local Jurisdiction Vulnerability

None of the Central Region counties included landslide in their hazard mitigation plan risk assessments. Accordingly, no loss estimates were made for locally identified critical facilities and infrastructure.

### Specific Areas of Concern

State Route 87 is a prominent and well-traveled corridor that serves the Phoenix Metropolitan area as a primary access to the Mogollon Rim country. Loss of use due to past or future landslide-based closures has had, and will have, a significant negative impact on the tourism economy of Rim country communities like Payson, Strawberry, Pine, Star Valley, Heber-Overgaard, and Forest Lakes.



Map 30: Landslide Hazard for North Region

## South Region

The South Region is the least vulnerable region in the state, largely due to the small mileage of exposed roadway.

### State-Owned CFI Exposure and Loss Estimates

None of the state-owned CFI are located in, or within 1,000 feet of, the identified landslide hazard zones. Approximately 5.4 miles of state-owned roadway is located in, or within 1,000 feet of, an identified landslide hazard zone, with the longest continuous segment being 2.4 miles and the shortest being less than 0.5 miles

### Vulnerable Population Groups

The 2015 estimated total population for the South Region is 1,458,367 people. Approximately 0.016% of the total population, or 232 persons, are located within the high landslide hazard areas.

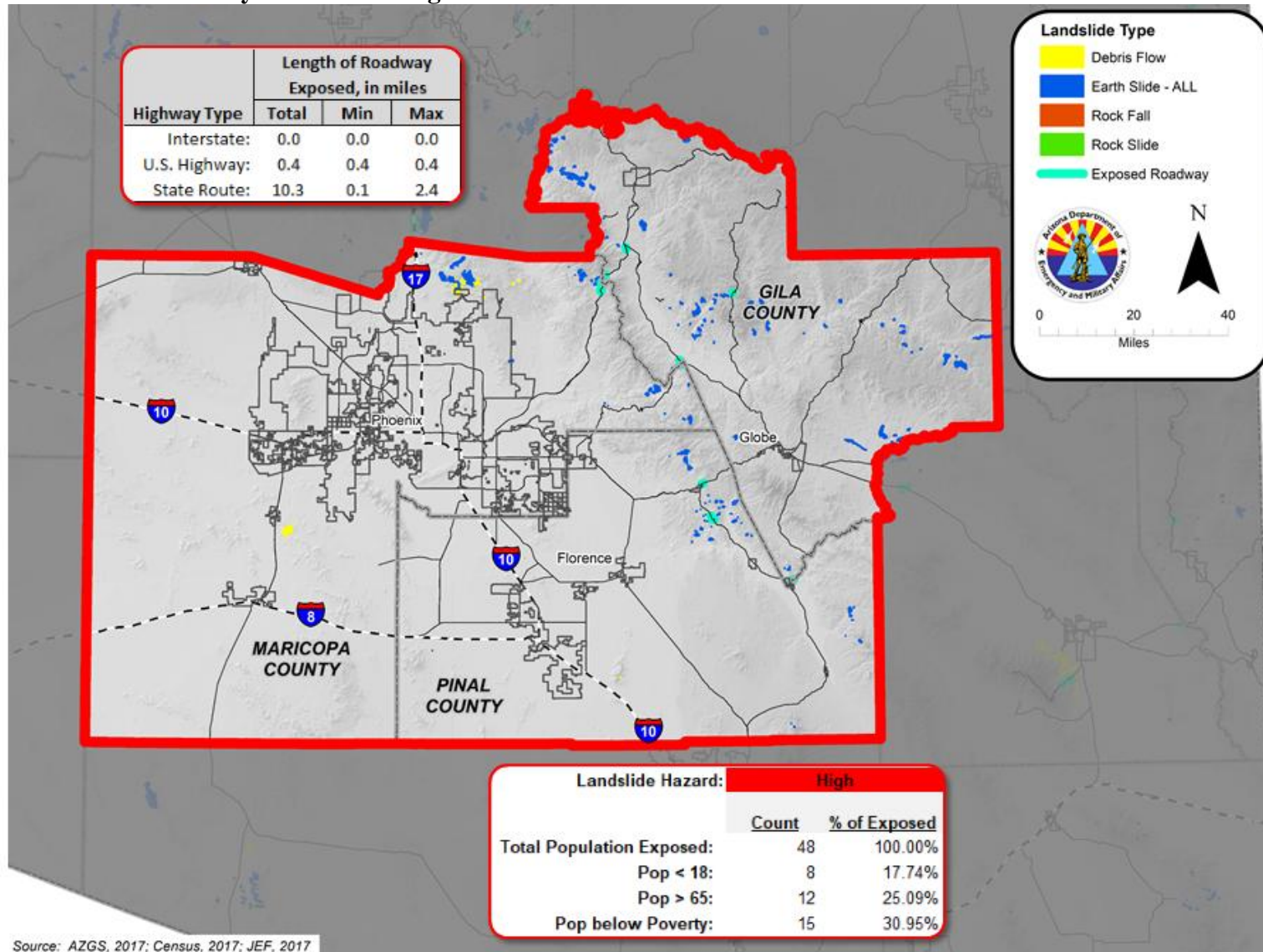
On average, approximately 12.7% of the South Region population is estimated to have a Limited English Proficiency (LEP). Assuming the percentage is equally applied across the whole region's population, roughly 30 LEP persons (12.7% of 232) are estimated to be located within the high landslide hazard areas.

### Local Jurisdiction Vulnerability

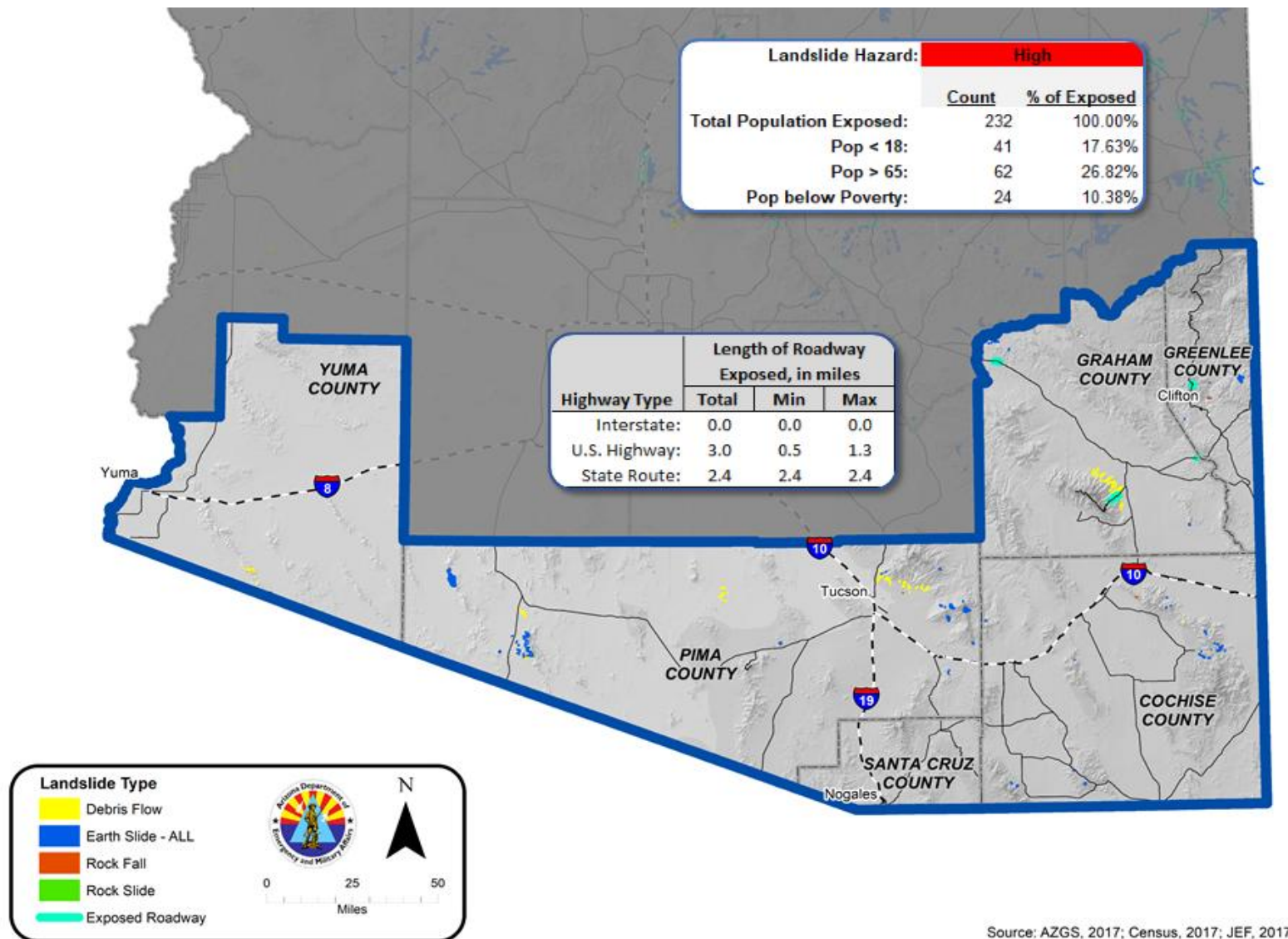
Pima County included landslide in their risk assessment but did not specifically estimate quantitative landslide related losses for locally identified critical and non-critical facilities. The Pima County plan did note that historic losses from the Sabino Canyon debris flow event of 2006 as exceeding \$1 million and that potential remains for similar losses.

### Specific Areas of Concern

The steep upper slopes of the Santa Catalina Mountains north of Tucson are prone to debris flows, rock falls, and translational landslides (Youberg, et.al., 2018). The mountains are heavily used by Tucson Metropolitan area residents for various kinds of outdoor recreation and access via the roadways along known debris flow areas on the Catalina Hwy up Mount Lemmon within the Coronado National Forest. Past debris flows have traveled down-the mountain slopes and into developed foothill areas, posing a moderate risk to property and infrastructure located along the areas closest to the base of the mountains. Bisbee and Clifton are also both situated at the base of mountainous terrain with elevated risks to landslide events.

**Map 31: Landslide Vulnerability for Central Region**





**Map 32: Landslide Vulnerability for South Region**



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## POTENTIAL CONSEQUENCES AND IMPACTS

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### Public

The best historical records for the state do not indicate any injuries or fatalities due to landslides. However, the risk posed by this hazard to the public increases as the population expands into previously uninhabited areas that are prone to landslide events. The most probable threat to human life is landslide events that occur without warning at roadways, such as rockfalls and slides that cause accidents or threaten motorists along highways. Debris flows into occupied properties will also threaten life safety. Lingering effects of road or facility closures will also adversely affect the traveling public.

### Property/Facilities/Infrastructure

Transportation infrastructure is potentially most at risk from landslides. Structures and buildings that are located within the path of a landslide typically sustain significant damage if not complete destruction. Other life-line infrastructure such as buried utilities, and poles and transmission towers carrying overhead utilities, can also sustain significant damage. Culverts and bridges receiving debris flows can be filled with dirt, cobbles and boulders, rendering them ineffective.

### Responders

Similar to the impact to the public, the risk level to responders will be dependent on the size, magnitude and location of the activity. Responders to this type of event will typically be rescuing those that have been isolated or possibly injured by rockfalls/slides. Additionally, those tasked with cleanup of rocks/debris are susceptible to injury as the removal of landslide materials may cause additional ground movement.

### Continuity of Operations/Delivery of Services

Overall, landslide is not a major threat to the state's ability to continue effectively functioning as records do not indicate state assets in high risk areas. The greatest threat to continuity of operations is posed by closures of transportation corridors and the resultant impacts to communities that are being disrupted for long periods of time as repairs are being made.

### Environment/Cultural

Landslide events by their very nature result in the substantial displacement or movement of earth material (soil and rocks), as well as any vegetation within the soil. Deposition of the moved mass into streams or rivers can result in something as simple as muddied waters, to full impoundment and/or diversion of the stream/river. Most landslide induced damming of watercourses will subsequently overtop and fail, sending a flood-wave downstream and causing significant erosion and scour. Other environmental effects can include impaired fish habitat (Schuster & Highland, 2004), residual scarring of the mountainside where exposed bedrock is all that remains from a landslide (Schuster & Highland, 2004), and destruction of archaeological sites located close to the stream or river like what has frequently occurred in the Grand Canyon (Griffiths, et.al., 2004). Conversely, in the long-term, there may be some benefits to the environment from coarse woody material being introduced to fish habitat areas of streams creating riffles and stream refuges (Schuster & Highland, 2004).

## **Economic/Financial Condition of Jurisdiction**

When a vital transportation corridor is blocked or damaged, the costs to the local jurisdiction can be significant. Some transportation routes in Arizona are not easily detoured and alternative roads, if available, may take hours longer. This particularly impacts remote communities where road damage can disrupt local services in the delivery of goods, interrupt employment, and impede access to health, educational, and social services. Other economic impacts could include lost sales tax revenue, disruption to commercial transport due to road and rail closures, revenue losses associated with disrupted utility service, and the cost of delays and diversions on transport networks (Winter, et.al., 2016).

## **Public Confidence in Jurisdiction's Governance**

As is typical of most natural hazards, swiftness of response and repair to a landslide event is critical. The potential for significant disruption of transportation networks and livelihoods can erode confidence in jurisdiction's ability to address the situation and restore function. It is in the jurisdiction's best interest to keep the public well informed of the damage extent, status of repairs and provide realistic expectations. Doing so may have a positive impact on the public's confidence level by letting them know the situation is being resolved and is controlled. Lack of communication can be mistaken for lack of action, resulting in frustration, anger, negativity, and distrust.

## **Cascading/Secondary Impacts**

Landslides can alter watercourses and direct flooding into areas not previously flooded. Broken utilities can lead to short-term shortages of water, gas, and other fuels. Increased fuel consumption and carbon emissions due to detour or alternate travel routes may occur.

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## LEVEE FAILURE

Levees have been part of the Arizona landscape for centuries, first along rivers and streams and then in agricultural communities to protect fields and facilitate irrigation. In urban areas, flood control systems have been constructed to increase the amount of developable land and to protect existing populations and infrastructure from flooding.



Clifton Levee along San Francisco River (looking southerly)  
Source: Gila Valley Central, photo by [Gualterio Casias](#)

Levees impound water above the natural prevailing grade or natural conveyance of a watercourse, creating an artificially constrained floodway. Areas protected by a levee, referred to as leveed areas, become the areas at-risk during a levee failure event. Levees are usually artificial structures comprised of earthen, cement stabilized aggregate (CSA) or roller compacted concrete (RCC) embankments, or structural concrete or steel walls. A levee is typically constructed parallel and adjacent to an existing watercourse. In some cases, the levee will function as a diversion structure that will re-direct floodwaters along an alignment that allows for positive flow along the levee to the intended outlet. All of Arizona's levees are for flood control.

Levee failures result in an uncontrolled release of water to the leveed areas, with potentially catastrophic impacts. Failures may be attributed to a variety of modes and causes. The three most common are: 1) foundation leakage and piping, 2) overtopping, and 3) embankment erosion.

In 2007, Congress established the National Committee on Levee Safety (NCLS) to develop recommendations for a National Levee Safety Program (NLSP). The NCLS, with guidance from Congress, developed the following definition for a levee: *"A manmade barrier (embankment, floodwall or structure) along a watercourse constructed for the primary purpose to provide hurricane, storm, and flood protection relating to seasonal high water, storm surges, precipitation and other weather events; and that normally is subject to water loading for only a few days or weeks during a year. Levees also may be embankments, floodwalls and structures that provide flood protection to lands below sea level and other lowlands and that may be subject to water loading for much, if not all, portions of the year, but that do not constitute barriers across watercourses or constrain water along canals."*

For the purpose of administering the National Flood Insurance Program (NFIP), FEMA provides accreditation for levee systems that are certified to meet the FEMA standards for major storm related flood risk reduction. In that capacity, FEMA defines levees as: *"man-made structures, usually earthen embankments designed and constructed in accordance with sound engineering practices to contain, control or divert the flow of water so as to provide protection from temporary flooding."*

In November 2017, Governor Ducey received a letter from the United States Army Corps of Engineers (USACE) notifying the Governor of the Congressional authorization of USACE to work with interested states and levee owners/operators to conduct an inventory and review of levees across the nation. The purpose of the action is to work with Arizona agencies to inventory, review and assess critical information for levees within Arizona, with a particular focus on levees not currently identified to be within USACE authority. The collected information will be included in the USACE's National Levee Database (NLD), which is publicly available and used to promote awareness of the benefits and flood risks associated with levees.

In February 2018, the USACE met with state officials and local levee owners and operators to kick-off the effort. Reports and deliverables are anticipated in summer 2018. One work product will be to assign a Levee Safety Action Classification (LSAC) value to each levee studied. The LSAC will provide state and local officials with a risk-based aid to determine mitigation priorities.



Non-levee embankment failures in Pinal County  
Source: Pinal County MJHMP, 2015

ADWR will serve as the state's lead agency for levee safety. By participating in the USACE project and coordinating with FEMA through the Cooperating Technical Partnership (CTP) program, ADWR will be able to facilitate with FEMA, USACE and local officials to better inspect, maintain, and track levees within their communities. The State of Arizona, USACE, and FEMA will have better data and information about levees in the administration of national and regional programs. Participation will not require anything to be built new, but will take greater advantage of FEMA's CTP program, and the USACE Silver Jackets program and NLD inventory and review project, to improve knowledge, collaboration, and capacity of local entities.

## HISTORY

The occurrence of significant levee failures has been limited in Arizona. Since 1966, there have not been any levee-specific state or federal declarations; however, levee failures related to major flooding events receiving state and federal declarations, such as those for the 1978 and 1993 floods, have occurred. Details of those incidents are described more thoroughly below.

There are no recorded failures of FEMA accredited levees for Arizona. There have, however, been several damage-producing failures of non-accredited levees, and embankments that were intended to function as levees, as follows:

- February 2005 - Smaller dikes along the Gila River in the Town of Duncan broke allowing water to backup into the town. Damage occurred to a residence near Duncan High School, and a trailer downstream of the high school. Also, Hwy 70 near the high school was covered with four feet of water and the approach ramps to the highway were overtopped with flowing water. East Avenue and low-lying areas in the west end of Duncan were evacuated on the evening of Saturday February 12, 2005. The railroad tracks also on the west end of



Duncan were covered with water and power went out in the west side of the town. Damages were estimated at nearly \$1.5 million (NCDC, 2009).

- December 2004 - A piping failure developed through the Winslow Levee along a sand lens located in the foundation soils below the levee. Entry paths to the sand layer were believed to have been caused by desiccation cracks, root channels, and/or rodent burrows. Emergency repairs to the levee were estimated at \$75,000 (Navajo County BOS, 2005; USACE, 2016).



2004 Winslow Levee Piping Failure – Landslide photos  
Source: USACE, 2016

- January 1993 - A 345-foot-long section of the Winslow Levee breached by overtopping and flooded the Ames Acres, Bushman Acres, and Winslow Plaza subdivisions. The resulting flooding inundated 204 parcels and 140 structures and required the evacuation of 900 people for as long as three days. Fifty homes were flooded up to four feet deep. One business and one farm received damages. At McHood Park the recreational lake silted up. The Corps of Engineers repaired the breach during the flood at a cost of \$350,050. Navajo County worked in 24-hour shifts to continue reinforcing the breach (USACE, 1994 and NCDC, 2009).
- January 1993 - The National Guard was called out to repair and reinforce the dike around San Lucy cemetery, near Gila Bend. Three houses north of Gila Bend were inundated from the rising water from Painted Rock Reservoir. Crops and fields were also inundated by floodwaters (USACE, 1994).
- December 1978 - The Gila River near Duncan reached a flow of nearly 60,000 cfs, breaching the existing levee embankments and severely damaging local infrastructure, homes and stores, and agricultural properties. The total damage of the flood was estimated at over \$2.5 million (Greenlee County Hazard Mitigation Plan, 2016).
- October 1972 - Gila River flooding of the Duncan Valley occurred when the levees protecting the Town of Duncan were overtopped and eroded. Most of the Town of Duncan was inundated with water up to four feet deep, and several adobe structures were destroyed or sufficiently damaged to require demolition. Silt over four inches deep in many places was deposited in yards and inside homes and stores ruining contents. Floors buckled, and foundations and walls cracked in several homes because of settling. The largest single structural loss was the elementary school building of the Duncan Unified School District. Total non-agricultural damage in Duncan Valley was over \$1.5 million, nearly all of which was in the Town of Duncan (FEMA, 2007).

## PROBABILITY/EXTENT

The probability of a FEMA accredited or USACE authority failing is low for Arizona. According to the latest NLD date provided by the USACE to ADWR in February 2018, there are 38 and 313

USACE authority and non-USACE authority levee systems within Arizona. Those systems equate to 57 and 878 total miles of USACE and non-USACE authority levees.

FEMA maintains a database of FEMA accredited levees as a part of the National Flood Hazard Layer (NFHL). Areas of reduced flood risk protected by a levee, are specially designated as such on FEMA maps and in the NFHL database. These special FEMA zones are considered a “best available” data source for mapping potential levee failure zones that may exceed the high flood hazard zones in the flood section of this report. The NLD also contains a data layer that shows the leveed areas for most of the USACE authority levees; however, currently, the NFHL data-set is more comprehensive. This may change once the USACE completes the inventory and review process, and future updates should query the NLD as a possible source for defining levee failure hazard areas.

Map 33 shows a statewide depiction of FEMA accredited levees and the reduced flood risk zones (or leveed areas) that are protected by the levees.

## **WARNING TIME**

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Once initiated, a levee failure can occur very rapidly, with a sudden, uncontrolled release of the stored or impounded water. Warning times for populations located in the leveed areas are dependent upon the speed of the flood-wave and distance from the breach. In most cases for Arizona, this is usually measured in tens of minutes. Extreme weather events with a potential to trigger or cause a failure will also have at least hours of warning if not a few days.

## **FUTURE CONDITIONS**

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### **Climate Considerations**

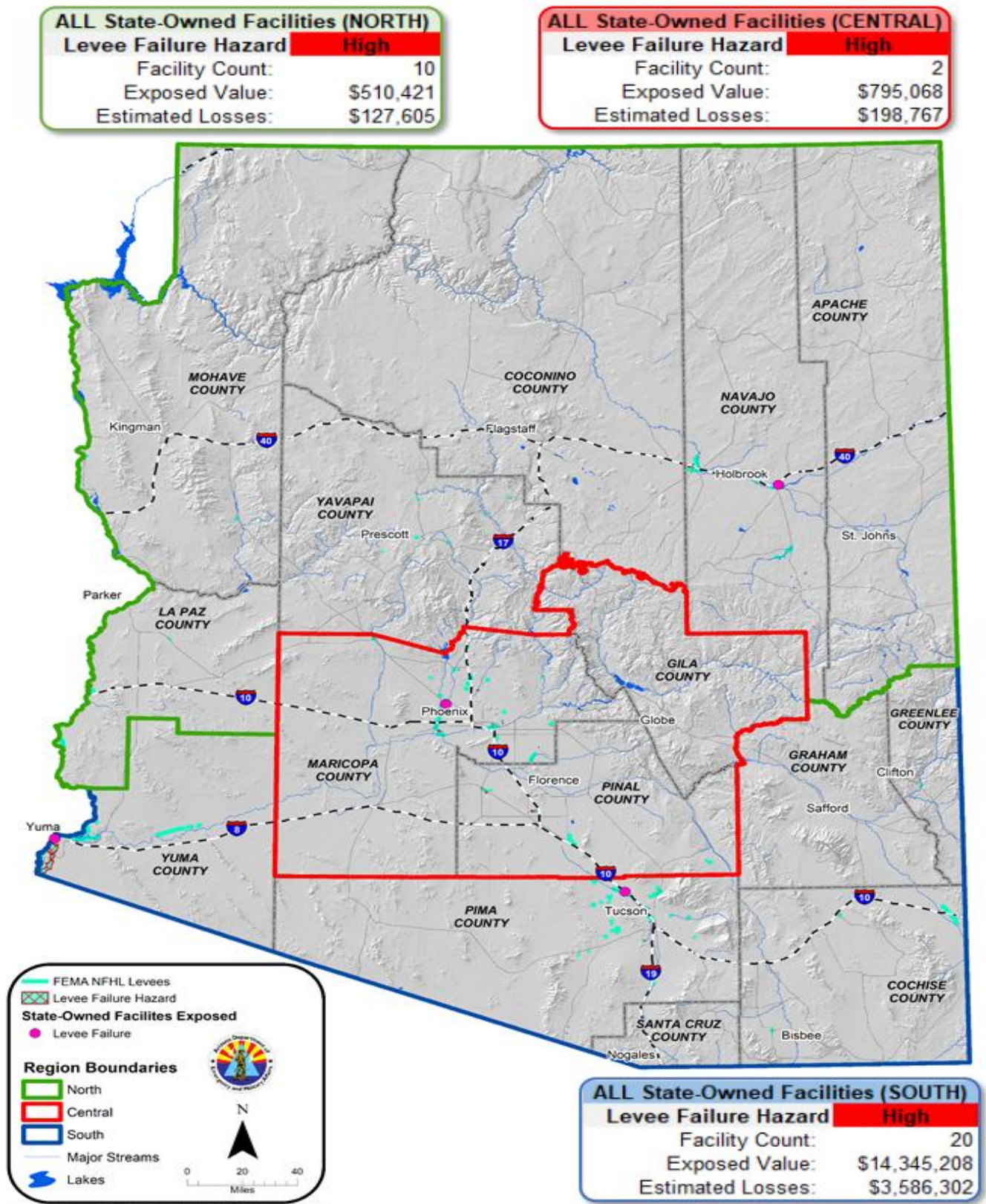
From a levee safety perspective, the primary climate change impacts will be related to potential changes in the way precipitation and resultant flood patterns may vary, and influence of the potential for increased wildfire activity. The National Climate Assessment (NCA) report (Garfin, et.al., 2014) notes that one of the anticipated impacts of climate change for the Southwest is a reduction in average annual precipitation and streamflow volumes. The report and supporting documents also indicate that winter storm intensities are anticipated to increase, which may lead to increased event-based flooding. The NCA report also notes that winter precipitation will be less in the form of snow and more frequently rain, which may indicate more frequent winter flooding. The overall flooding conditions for watersheds upstream of levee facilities could also be exacerbated by the potential for reduced vegetation due to increases in drought or post-wildfire flooding conditions.

### **Changes in Development**

The two, primary development related impacts to levee failure are:

- A phenomenon referred to as “development creep” happens when development begins to encroach into the leveed areas, increasing the exposure of population and infrastructure to the risk of post failure inundation.
- Potential changes in watershed rainfall-runoff characteristics due to the addition of significant impervious areas can translate into increased runoff volumes that may exceed or challenge the design capacities of the levee structures.

Map 33: Levee Failure Hazard Statewide





### North Region

Apache, La Paz, and Navajo Counties have experienced little to no growth of any significance over the past five years, nor is there any major growth or development in levee failure areas anticipated over the next five years. Moderate growth has occurred in Coconino, Mohave and Yavapai Counties and the trends of the past five years are anticipated to continue over the next five years with most of the growth being concentrated around existing population centers. Areas of anticipated significant growth that may extend into levee failure areas are identified in the Flagstaff and Tusayan (Coconino), Prescott Valley and Chino Valley (Yavapai), Bullhead City and Lake Havasu City (Mohave), plus several populated areas within the unincorporated areas of Coconino, Mohave, and Yavapai Counties. None of the anticipated development is expected to alter any of the current dam hazard and safety ratings.

### Central Region

Significant growth has occurred in Maricopa and Pinal Counties over the past five years, and primarily in the build-out of previously planned residential, industrial and commercial areas. Growth in Gila County has been mostly limited to the Payson area. The federal and local levees impacting Maricopa County have been actively studied and evaluated for failure inundation limits, with small pockets of the county being situated within an identified levee failure inundation zone. Development over the next five years will at least partially occur within these mapped areas, however the risk of failure for most of the levees impacting the area are low due to the high level of maintenance and mitigation of potential failure modes. Planned growth in Pinal County areas subject to levee failure inundation is low to moderate and anticipated in or near Apache Junction, Coolidge, Florence, Maricopa, areas along the Santa Cruz River, and portions of the San Tan Valley.

### South Region

Pima and Yuma Counties have experienced moderate growth over the past five years in some locations and population declines in others. Cochise County experienced moderate growth within Douglas and Sierra Vista, but generally a decline in the overall population. Graham County saw limited growth in the Pima-Safford-Thatcher area that is mostly attributable to the new Freeport McMoRan mining operations. Santa Cruz and Greenlee Counties have experienced limited to no significant growth. Moderate growth is expected to continue in Pima and Yuma Counties, primarily near or within the Tucson and Yuma Metropolitan areas, expanding the exposure to existing levee failure inundation zones. Future growth into levee failure zones within Cochise, Graham, Greenlee, and Santa Cruz Counties is not anticipated to be significant.

## VULNERABILITY ASSESSMENT

The estimation of potential exposure to the identified levee failure inundation hazards was accomplished by using GIS mapping and analysis tools to intersect the vulnerable population and state-owned critical facilities and infrastructure (CFI) data with the inundation limits which are considered the high hazard areas for this analysis. The loss calculations assume that exposed structures are subject to a loss-to-exposure ratio of 0.25 (or 25% damaged). The exposure loss estimates presented are based on a single event and aggregated to the entire region.

Three of the 15 county multi-jurisdictional hazard mitigation plans included levee failure in their risk assessment. Further details are summarized by region in the sections below.

## North Region

The North Region is the second-most vulnerable state region when considering the history of events, the exposure estimates, and number of local plans that included levee failure in their risk assessment.

### State-Owned CFI Exposure and Loss Estimates

A total of 10 state-owned CFI, or 76.9% of the statewide exposure, are located within levee failure inundation zones. The facilities exposed to levee failure inundation represent a total exposed replacement value of \$500,000, with an estimated \$130,000 in potential losses.

Additional state-owned facilities vulnerable to levee failure inundation hazards are the Arizona Department of Transportation (ADOT) operated and maintained freeways, highways and state routes located within the inundation zones. The drainage facilities (bridges, culverts, and channels) constructed with the ADOT roadways are not expected to have capacity for handling the types of flows associated with a levee failure. Typical impacts might include erosion of roadway embankments and pavements, culvert and bridge failures, and significant sedimentation.

### Vulnerable Population Groups

The 2015 estimated total population for the North Region is 772,157 people. Approximately 0.36% of the total population, or 2,800 persons, are exposed to levee failure inundation hazards. Exposure estimates for at-risk population groups like persons under 18-years of age, over 65-years of age, and those living at or below poverty level.

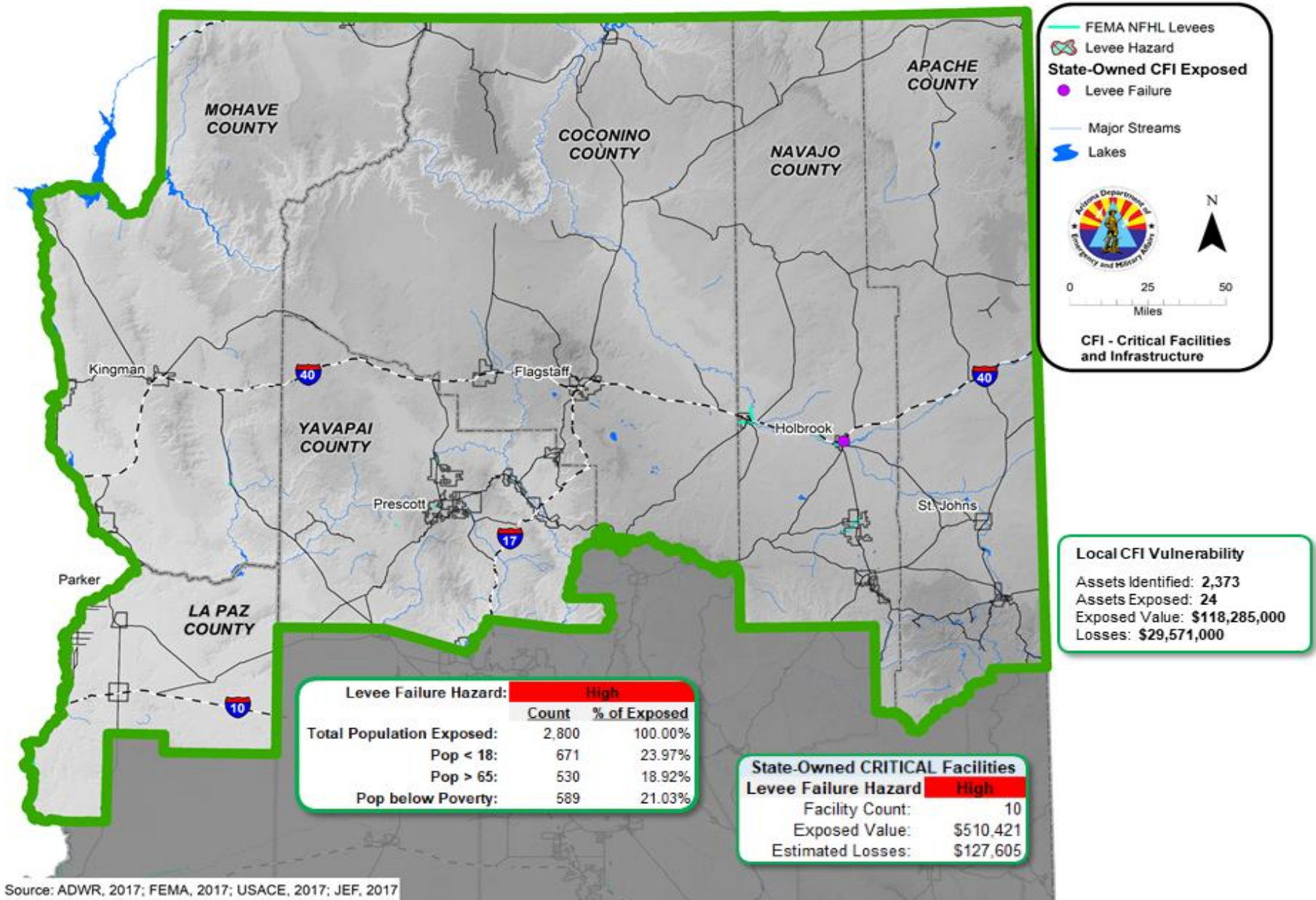
On average, approximately 7.3% of the North Region population is estimated to have a Limited English Proficiency (LEP) (U.S. Census Bureau, 2016). Assuming the percentage is equally applied across the whole region's population, roughly 205 LEP persons (7.3% of 2,800) are estimated to be exposed to levee failure inundation.

Local Jurisdiction Vulnerability – Local hazard mitigation plans for the North Region identified a total of 24 assets with a total replacement value of \$118.3 million. Total potential losses to local CFI for levee failure inundation were estimated at \$29.6 million.

### Specific Areas of Concern

The Winslow Levee and other levees along or near the Little Colorado River in Navajo County have a history of failure risk, and especially in and around the City of Winslow. An additional area of concern regarding levees located near or within North Region communities, is the possibility for significant post-wildfire flooding that could significantly overwhelm existing capacities.



**Map 34: Levee Failure Vulnerability for North Region**

## Central Region

Among the three state regions, the Central Region has the most significant vulnerability when considering the history of events, the exposure estimates, and number of local plans that included dam and/or levee failure in their risk assessment. Alternately, the Central Region arguably has the greatest amount of resources for active dam and levee maintenance and repair, as well as modeling and mapping of hazard areas.

### State-Owned CFI Exposure and Loss Estimates

A total of 2 state-owned CFI, or 15.4% of the statewide exposure, are located within levee failure inundation zones. The facilities exposed to levee failure inundation represent a total exposed replacement value of \$800,000 with an estimated \$200,000 in potential losses.

State-owned and maintained roadways and infrastructure within the metropolitan Phoenix area are designed to meet local drainage requirements, and therefore are protected to 1% annual flood level. Although better than their rural counterparts, the numerous drainage facilities (bridges, culverts, and channels) constructed with the ADOT roadways are still not expected to have capacity for handling the types of flows associated with a levee failure. Typical impacts might include erosion of roadway embankments and pavements, culvert and bridge failures, and significant sedimentation.

### Vulnerable Population Groups

The 2015 estimated total population for the Central Region is 4,604,414 people. Approximately 0.68% of the total population, or 31,186 persons, are exposed to levee failure inundation hazards. Exposure estimates for at-risk population groups like persons under 18-years of age, over 65-years of age, and those living at or below poverty level.

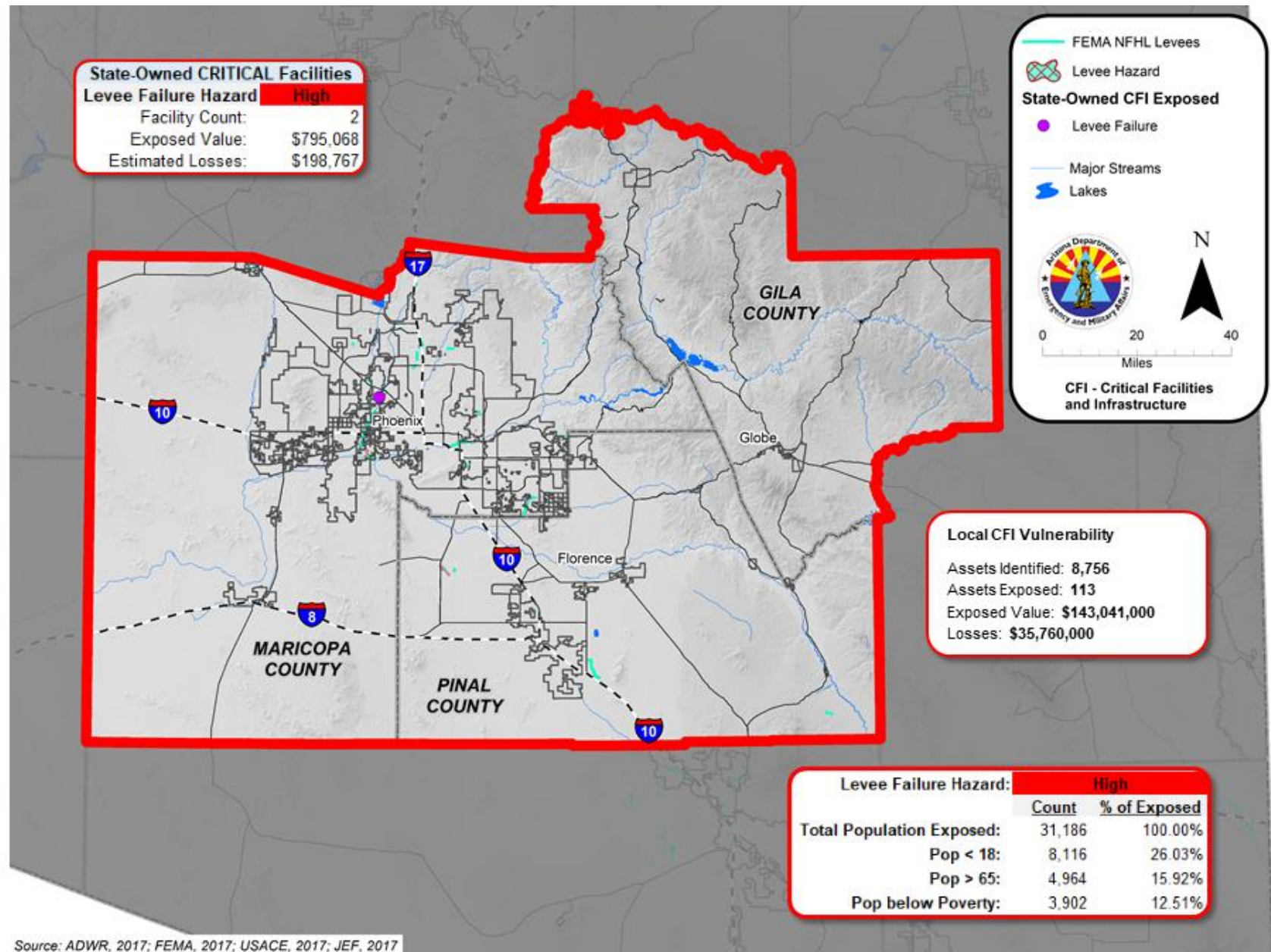
On average, approximately 6.7% of the Central Region population is estimated to have a LEP (U.S. Census Bureau, 2016). Assuming the percentage is equally applied across the whole region's population, roughly 2,079 LEP persons (6.7% of 31,186) are estimated to be exposed to levee failure inundation.

### Local Jurisdiction Vulnerability

Local hazard mitigation plans for the Central Region identified a total of 113 assets with a total replacement value of \$143.0 million. Total potential losses to local CFI for levee failure inundation were estimated at \$35.8 million.

### Specific Areas of Concern

There are numerous non-accredited and unstudied levee embankments located in the Central Region that were constructed by various entities and are still in place today. A detailed analysis of those structures is not currently available. The presence of those facilities can give residents a false sense of security, and a failure could result in significant damage to downstream properties. These non-accredited embankments are not reflected in the vulnerability analysis numbers presented herein but may become available for future updates via the USACE NLD discussed earlier.

**Map 35: Dam and Levee Failure Vulnerability for Central Region**



## South Region

The South Region is the least vulnerable state region when considering the history of events, the exposure estimates, and number of local plans that included dam and/or levee failure in their risk assessment.

### State-Owned CFI Exposure and Loss Estimates

One state-owned CFI, or 7.7% of the statewide exposure, is located within levee failure inundation zones. The facilities exposed to levee failure inundation represent a total exposed replacement value of \$560,000, with an estimated \$140,000 in potential losses.

Additional state-owned facilities vulnerable to levee failure inundation hazards are the ADOT operated and maintained freeways, highways and state routes located within the inundation zones. The drainage facilities (bridges, culverts, and channels) constructed with the ADOT roadways are not expected to have capacity for handling the types of flows associated with a dam or levee failure. Typical impacts might include erosion of roadway embankments and pavements, culvert and bridge failures, and significant sedimentation.

### Vulnerable Population Groups

The 2015 estimated total population for the South Region is 1,458,367 people. Approximately 1.47% of the total population, or 21,382 persons, are exposed to levee failure inundation hazards. Exposure estimates for at-risk population groups like persons under 18-years of age, over 65-years of age, and those living at or below poverty level.

On average, approximately 12.7% of the Central Region population is estimated to have a LEP (U.S. Census Bureau, 2016). In Santa Cruz and Yuma, this number averages 23.5%. Assuming the percentage is equally applied across the whole region's population, roughly 2,708 LEP persons (12.7% of 21,382) are estimated to be exposed to levee failure inundation.

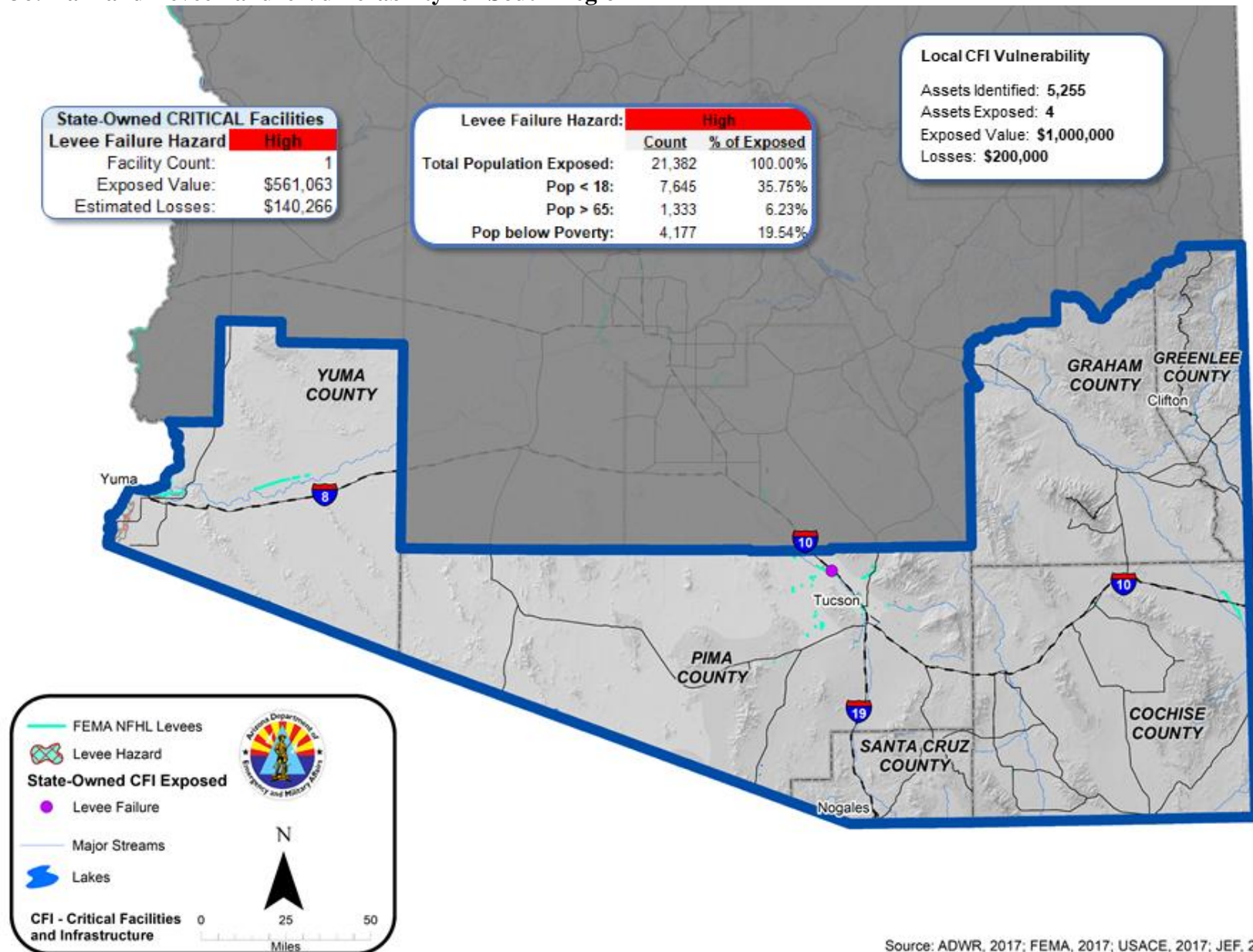
### Local Jurisdiction Vulnerability

Local hazard mitigation plans for the South Region identified a total of four assets with a total replacement value of \$1 million. Total potential losses to local CFI for levee failure inundation were estimated at \$200,000.

### Specific Areas of Concern

There are numerous non-accredited and unstudied levee embankments located in the South Region that were constructed by various entities and are still in place today. A detailed analysis of those structures is not currently available. The presence of those facilities can give residents a false sense of security, and a failure could result in significant damage to downstream properties. An example is the 1972 failure of the Duncan embankments on the Gila River. According to FEMA (2007), residents were provided with ample warning to evacuate themselves and even some of their belongings, but most did not leave their homes. These non-accredited embankments are not reflected in the vulnerability analysis numbers presented herein but may become available for future updates via the USACE NLD discussed earlier.



**Map 36: Dam and Levee Failure Vulnerability for South Region**

## **POTENTIAL CONSEQUENCE AND IMPACTS**

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### **Public**

The resultant flooding from levee failures can result in injuries and loss of life to the general public located within the inundation zone. Fatalities are usually due to drowning. Another very disruptive effect is when this hazard leads to isolation or evacuation. The evacuation alone can cause considerable trauma and stress for those affected, not to mention those who must find shelter for their pets and livestock. Long-term recovery will take months if not years, and in some cases permanent relocation may be required.

### **Property/Facilities/Infrastructure**

The flood-wave typically released by a levee failure can be very destructive both in force and flooding depths. Damage to most impacted, above ground property, structures, and infrastructure is likely to be catastrophic, with the worst impacts being closest to the breach or failure location and dissipating with distance. The potential for significant erosion and scour also threatens buried infrastructure.

### **Responders to the Incident**

Much like the dangers of flooding, levee failure incident responders may experience injury due to debris, drowning, electrocution, cold stress and exposure to hazardous materials. Because flooded disaster sites are unstable, clean-up workers might also encounter sharp, jagged debris, biological hazards in the flood water, exposed electrical lines, blood or other body fluids, and animal and human feces and remains. Responders are prone to the same dangers as the general public is, only on a higher level as they may be putting themselves in harm's way by performing rescue activities.

### **Continuity of Operations/Delivery of Services**

Potential levee failures as currently mapped are not expected to have a significant effect on the state's abilities to provide operations and services.

### **Environment/Cultural**

Levee failures result in flooding with the addition of a flood-wave pulse that dissipates as it moves further into the leveed area. The impacts to environmental and cultural resources are a magnified version of what might occur with regular flooding. As such, please refer to the Flooding Section for further discussion.

### **Economic/Financial Condition of Jurisdiction**

Levee failures result in flooding with the addition of a flood-wave pulse that dissipates as it moves further into the leveed areas. The impacts to the economic and financial condition of the state is a magnified version of what might occur with regular flooding. As such, please refer to the Flooding Section for further discussion.

## Public Confidence in Jurisdiction's Governance

Levee failures result in flooding with the addition of a flood-wave pulse that dissipates as it moves further into the leveed areas. Effects on the public's confidence in the state's governance are a magnified version of what might occur with regular flooding. As such, please refer to the Flooding Section for further discussion.

## Cascading/Secondary Impacts

Levee failures result in flooding with the addition of a flood-wave pulse that dissipates as it moves further into the leveed areas. Development of cascading or secondary impacts is a magnified version of what might occur with regular flooding. As such, please refer to the Flooding Section for further discussion.

## RESOURCES

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## SEVERE WIND

For this Plan, the hazard of severe wind encompasses all climatic events that produce damaging winds. For Arizona, severe winds typically result from either extreme pressure gradients that usually occur in the spring and early summer months, or from thunderstorms. Occasionally, tropical storm activity (remnant hurricanes) can be accompanied by severe winds, but the wind speeds usually dissipate by the time the tropical storm front approaches the state, with greater threat to the southern portions of the state. Thunderstorms can occur year-round and are usually associated with cold fronts in the winter, monsoon activity in the summer, and tropical storms in the late summer or early fall.



Dust Storm in Downtown Phoenix - 2002  
Source: Pinterest - Patti Pettigrew

Three types of damaging wind-related features may accompany a typical Arizona thunderstorm; 1) downbursts, 2) straight-line winds, and infrequently, 3) tornadoes.

Downbursts are columns of air moving rapidly downward through a thunderstorm. When the air reaches the ground, it spreads out in all directions, creating horizontal wind gusts of 80 mph or higher. Downburst winds have been measured as high as 140 mph. Some of the air curls back upward with the potential to generate a new thunderstorm cell. Downbursts are called macrobursts when the diameter is greater than 2.5 miles, and microbursts when the diameter is 2.5 miles or less. There can be either dry or wet downbursts, where the wet downburst contains precipitation that continues all the way down to the ground, while the precipitation in a dry downburst evaporates on the way to the ground, decreasing the air temperature and increasing the airspeed. In a microburst, the wind speeds are highest near the location where the downdraft reaches the surface, and are reduced as they move outward due to the friction of objects at the surface. Typical damage from downbursts includes uprooted trees, downed power lines, mobile homes knocked off their foundations, block walls and fences blown down, and porches and awnings blown off homes. Aircraft caught in the downdraft can be forced to the ground.

Straight line winds are developed similar to downbursts, but are usually sustained for greater periods as a thunderstorm reaches the mature stage. Straight line winds travel (or are pushed), parallel to the ground surface on the leading edge of a thunderhead, reaching speeds of 75 mph or higher. These winds are frequently responsible for generating the large dust and sand storms seen moving across the desert regions of Central and Southern Arizona. The blowing dust can reduce visibility to near zero, creating hazardous driving conditions.

Strong wind events not associated with thunderstorms can occur throughout the year, but are frequently strongest in the late winter to late spring months and can generate high-speed winds that last for hours and often include exceptionally strong gusts. The Flagstaff NWS office notes this type of wind events as strong pressure gradients, mesoscale events, channeled winds; Foehn/Chinook/downslope winds, and winds associated with tropical storm remnants.

A tornado is a rapidly rotating funnel (or vortex) of air that extends toward the ground from a cumulonimbus cloud. Most funnel clouds do not touch the ground, but when the lower tip of the

funnel cloud touches the earth, it becomes a tornado and can cause extensive damage. For Arizona, tornadoes are the least common severe wind to accompany a thunderstorm.

## HISTORY

The following are examples of significant severe wind events that have occurred in the state:

- June 26, 2016 - Up to 75 mph thunderstorm winds uprooted dozens of large trees from Winterhaven to Himmel Park in the City of Tucson. Many of the trees fell on apartment buildings, houses, and vehicles and the roof of a church suffered severe wind damage. For some residents, power was not restored for several days. One person was electrocuted after coming in contact with a live downed wire but survived. Damage was estimated at \$1 million (NCDC Storm Events Database).
- September 2014 - A severe squall line moved across the greater Phoenix Valley causing major damage to trees, power poles, roofs, cars, and small aircraft at several valley airports. Gusts exceeding 70 mph were measured, and reported damages exceeded \$200,000. In Pinal County, a wind-induced train derailment resulted in 30 cargo cars toppling over and off the tracks in Eloy (NCDC Storm Events Database).
- September 10, 2011 - Strong thunderstorm winds occurred on Tucson's south side for the second day in a row, downing numerous power poles, electric lines, street signs, and trees. As many as 25,000 were left without power. One power pole was downed on a trailer leading to the evacuation of the trailer park near East Drexel and South Country Club Roads. Another Tucson resident woke up to a power pole entering the dwelling. Part of a roof was also blown off a residence on Valencia Road, blowing across the road into another home damaging the roof. Damages were estimated to exceed \$500,000 (NCDC Storm Events Database).
- October 6, 2010. A record-breaking 11 tornados touched down in Coconino County. According to the NWS Flagstaff Office, two were EF-3, four were EF-2, two were EF-1, and three were EF-0. A total of 101 homes suffered various levels of damage across the touchdown zones, with the area of Bellemont being the hardest hit. The Flagstaff Meadows subdivision had three homes completely destroyed, nine homes with major damage, and 15 homes with minor damage. An RV retailer lost over 30 units with some being tossed onto I-40. Several vehicles along the I-40 corridor were flipped over, and Burlington northern Santa Fe railroad experienced a 20 rail car derailment (Coconino County, NCDC Storm Events Database).



Bellemont Tornado Damages – October 2010  
Source: Coconino County

- January 21, 2010 - Three large trees were blown over at Bell Road and 16th Street. A large tent at the Russo Steele Auction in Scottsdale near Mayo Blvd and Scottsdale Rd was destroyed and blown into nearby Loop 101 when winds collapsed the tent onto many classic cars. There was also small damage at a nearby Barrett Jackson Auction. Three minor injuries reported and losses were estimated to exceed \$1.5 million.
- August 28, 2008 - A series of strong thunderstorms moved across central and eastern Maricopa County with winds up to 85 mph, uprooting hundreds of trees and power lines, damaging aircraft and terminal buildings, blowing windows out of high rise buildings, causing \$20 million in property damage, fortunately no deaths were reported (NCDC Storm Events Database).
- July 21, 2008 - Microburst winds took down a total of 55 power poles in Mesa, leaving as many as 12,000 SRP customers without power. About 31 homes were damaged at a trailer park on North Recker Road, with four roofs blown off. On Southern Avenue near Power Road, 15 poles were knocked down with lines impacting seven vehicles, including a bus. There were two reported injuries with one attributed to cuts from broken glass. Total damages were estimated to exceed \$1 million (NCDC Storm Events Database).
- July 25, 2006 - Several cities throughout the central portion of Maricopa County had major wind damage as a series of thunderstorms and microbursts moved across the area. According to the Salt River Project, an estimated 65 power poles were blown down, in parts of Scottsdale, Tempe, and Mesa. At one point, about 20,000 customers were without power. Arizona Public Service reported about 8,000 customers were without power. At Phoenix Sky Harbor Airport, the official peak wind gust was 59 mph. However, winds at Williams Gateway Airport gusted to 86 mph and flipped a small twin-engine plane atop another aircraft. In Mesa, 35 schools reported damages due to the storm. There were also numerous trees and homes across the Phoenix Metro Area that were damaged by winds. Losses were estimated to exceed \$150 million (NCDC Storm Events Database).
- July 14, 2002 - A microburst event struck Sky Harbor Airport at the Postal facility and the West economy parking lot. A large thunderstorm complex, with strong microburst winds estimated at 100 mph struck Sky Harbor International Airport. Southerly winds and dense blowing dust initially spread across the East Valley and converged with a fast-moving thunderstorm in north Phoenix. These merging systems developed into a severe thunderstorm with winds that uprooted trees took down power poles and damaged homes and businesses near the airport. Several hangars sustained major damage. Flying debris damaged five commercial aircraft, several private planes and hundreds of cars in the nearby parking lots. Numerous flights were diverted during the overnight hours due to the debris that was scattered on the runway. Property damage was reported at \$30 million (NCDC Storm Events Database).
- July 14, 2002 - Two microbursts struck the Phoenix area. Winds from the first microburst heavily damaged the Arizona Public Service power sub-station at 7th Ave & Thomas. Widespread damage was reported across the greater Phoenix metropolitan area caused by the storm's high winds and heavy rainfall with up to two inches in 90 minutes. Utility companies reported that 22 power poles were downed, leaving at least 47,000 homes and businesses without electricity for many hours. Homes in Scottsdale and Ahwatukee were

struck by lightning and set on fire. The microburst caused an estimated \$20 million damages (NCDC Storm Events Database).

- July 14, 2001 - A microburst hit Scottsdale and Tempe with very strong winds and heavy rain. Many homes and businesses sustained damage, with at least 19 power poles blown down. One pole landed on a vehicle near Scottsdale and Indian Bend roads, killing the driver. About 6,000 residents were left without power, including the nearby Radisson Resort. Winds ripped the roofs off four homes in the McCormick Ranch area and dumped them up to two blocks away. Numerous trees were uprooted. A total of one fatality and \$5 million property damage were reported (NCDC Storm Events Database).
- August 16, 2000 - Strong thunderstorm wind gusts of 80-100 mph moved through the community of Golden Shores in Mohave County causing \$1 million in damage. Two mobile homes were destroyed, and 17 other mobile homes and frame houses were unlivable. Another 117 homes received minor damage. One injury occurred when the homeowner sought shelter in a tub in the mobile home's bathroom. As the mobile home rolled the toilet was ripped from its foundation and struck the homeowner in the head causing cuts and bruises. In addition, numerous pontoon boats were either flipped over or destroyed, and several windows were broken on homes and cars. The storm snapped several power lines which cut power, in turn cutting the community's water supply (NCDC Storm Events Database).
- August 14, 1996 - Severe thunderstorm winds caused damages to every town in the western half of the Phoenix Metropolitan Area. The hardest hit areas were in northwest Phoenix, Glendale, and Peoria. Other towns that sustained damage were Sun City, Surprise, El Mirage, Tolleson, Avondale, Goodyear, and Buckeye. Approximately 400 power poles were knocked down throughout these towns, 100 owned by SRP and 300 owned by APS. There were from 70,000-75,000 homeowner claims for about \$100 million in damage. Two juvenile detention centers, the Adobe Mountain Secure Facility and the Black Canyon Secure Facility, both in north Phoenix, sustained an estimated \$250,000 combined damage when strong winds damaged a perimeter fence, blew out a plastic glass window and damaged several roofs at the complex. Two support pillars under construction at the I-17 and Loop 101 interchange in north Phoenix buckled from the high winds, with an estimated \$250,000 damage (NCDC Storm Events Database).

## PROBABILITY/EXTENT

Based on history, the probability for a severe thunderstorm or high wind event to occur somewhere in the state, in any given year, is essentially one or 100%. In the last 10-years (2008-2017), there have been 476 days with reported severe thunderstorm events, or approximately 47.6 event-days per year on a statewide basis. For the same period, the number of event days associated with thunderstorms is 358, or 75% of the total. The remaining 118 event days are associated with non-thunderstorm events.

Again based on history, the probability for tornado events in Arizona is low, and especially when compared to national standards. In the last 10-years (2008-2017), there have only been nine damaging tornados (category EF1 or higher – see below) recorded for the whole state and six of those were generated by a single storm event in October 2010. On average, that is less than one damaging tornado a year. The National Centers for Environmental Information reports an



average of five tornados per year for Arizona<sup>1</sup>, which compares to 60-90+ tornados for central US states.

The strength and magnitude of severe wind events is primarily based on wind speed. Thresholds and categories are detailed below.

### **Thunderstorm or Other Non-Tornado High Winds**

The NWS considers a thunderstorm as severe if it produces hail at least one-inch in diameter, wind gusts of 58 mph or higher, or any tornadoes. When a severe thunderstorm has been detected by weather radar or one has been reported by trained storm spotters, the local NWS office will issue a severe thunderstorm warning. According to NCDC data, at least 2,647 severe thunderstorm or other non-tornado high wind event locations that recorded or estimated three-second wind gusts of over 58 mph were identified in Arizona between 1955 and 2017. During that period, three deaths, 146 injuries, and \$382.4 million in damages were reported.

The Beaufort Wind Scale provides a measure of overland wind magnitude versus expected damages. According to the Beaufort Scale, wind gusts of 55-63 mph can result in uprooted trees and considerable structural damage to poorly constructed buildings. Wind gusts between 64-73 mph can result in more widespread structural damage to moderately constructed buildings. Wind gusts over 74 mph are able to do widespread damage to moderately constructed buildings and even well-constructed buildings.

### **Tornadoes**

Tornado severity is measured using the Enhanced Fujita Scale. Table 9 provides a summary of the Fujita scale values with a general description of damage associations.

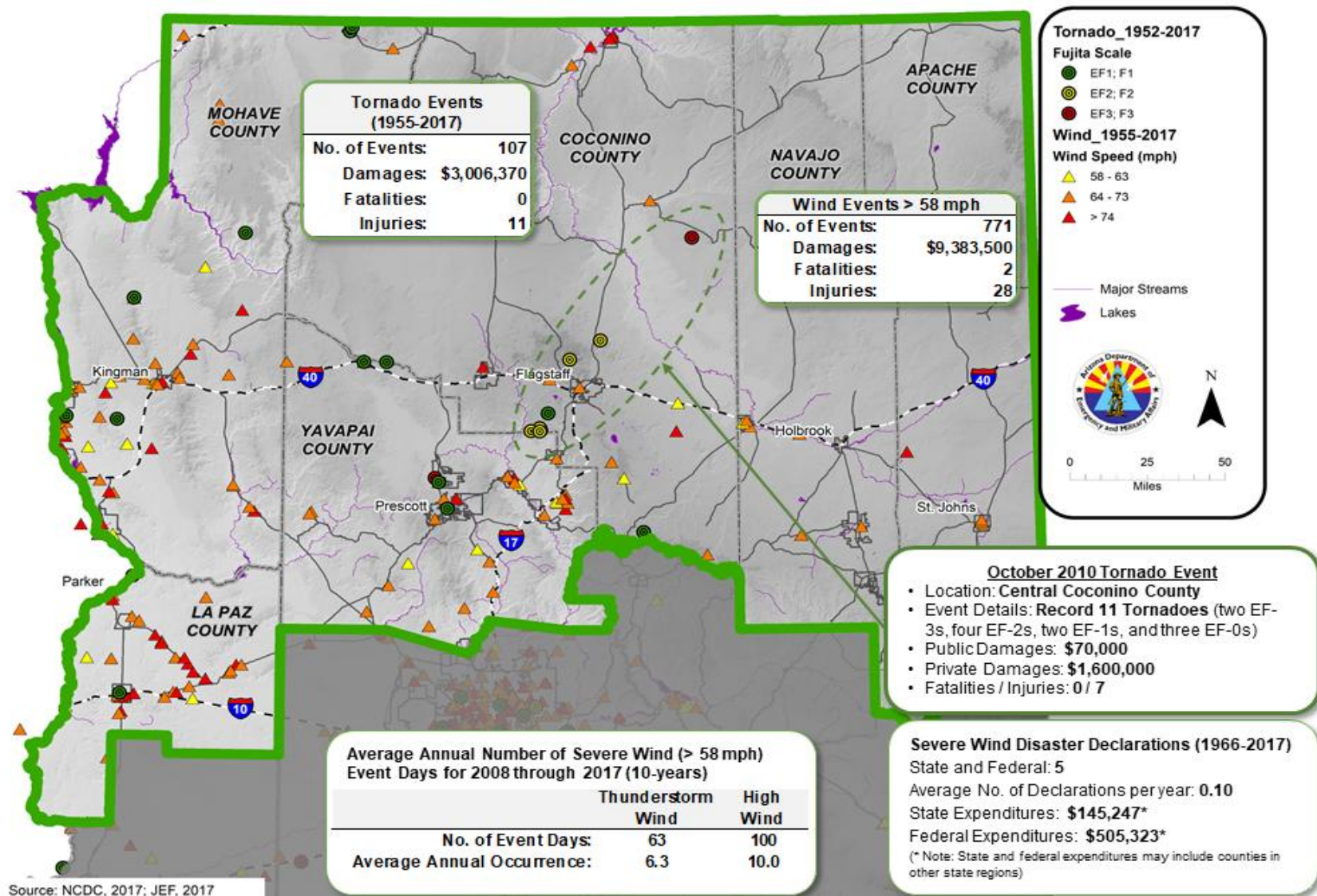
To date, Arizona has not experienced anything higher than an EF3 category tornado but has experienced many EF0, EF1, and to a lesser extent, EF2 tornadoes. According to the NCDC database, there were 247 tornadoes ranging from EF0 to EF3 on the Fujita scale(s) recorded across Arizona between 1952-2017. The total property damage was approximately \$48.5 million with three fatalities and 147 injuries. Total crop damage was approximately \$30,000.

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<sup>1</sup> NOAA National Centers for Environmental Information, USTornado Climatology, 2017, website data accessed at: <https://www.ncdc.noaa.gov/climate-information/extreme-events/us-tornado-climatology>

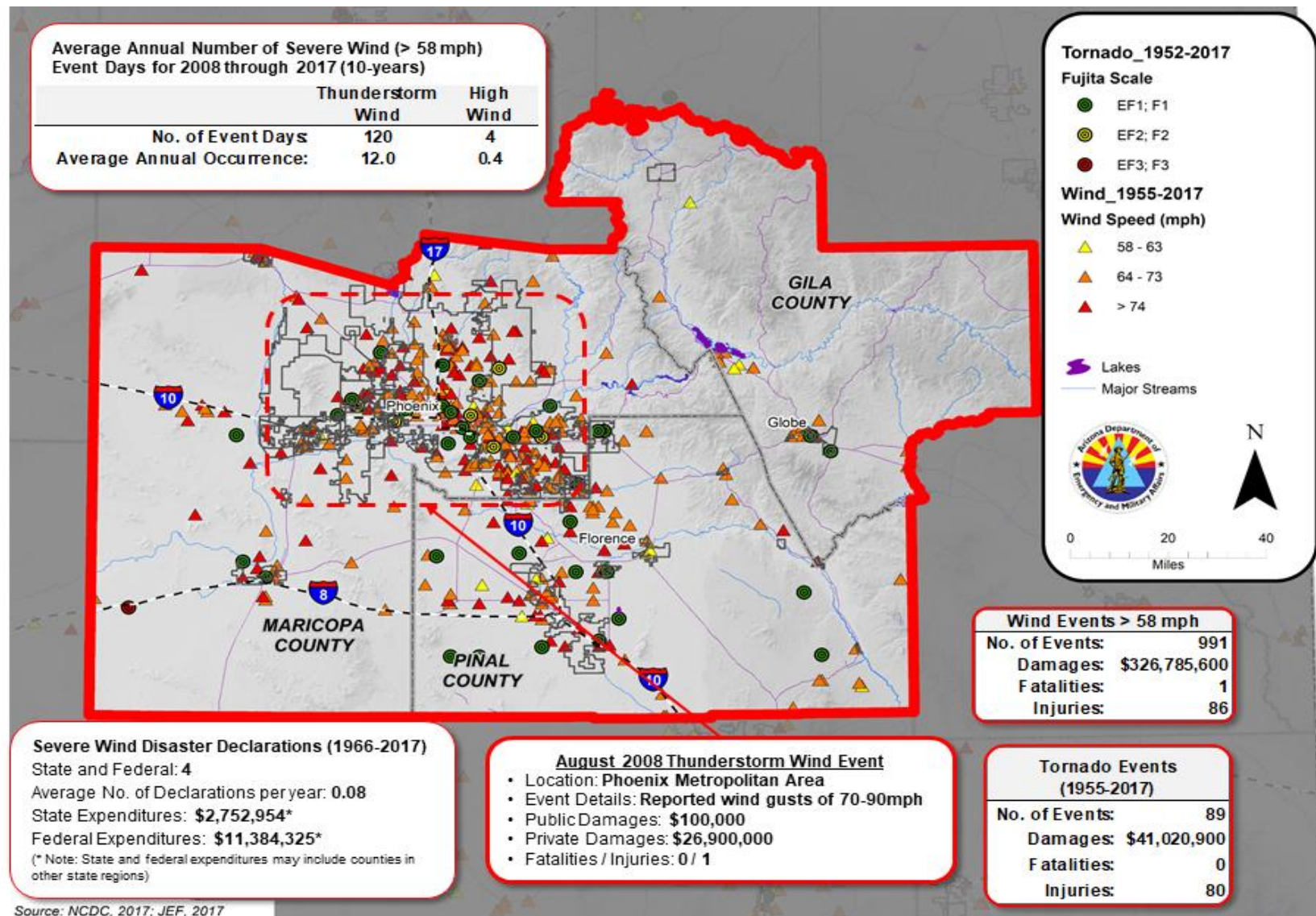
**Table 9: Tornado Scale Levels and Damage Descriptions**

Fujita Scale		Enhanced Fujita Scale		Damage Description
ID	Wind Speed (MPH)	ID	Wind Speed (MPH)	
F0	45-78	EF0	65-85	<b>Minor or no damage.</b> Peels surface off some roofs; some damage to gutters or siding; branches broken off trees; shallow-rooted trees pushed over. Confirmed tornadoes with no reported damage are always rated F0 or EF0.
F1	79-117	EF1	86-110	<b>Moderate damage.</b> Roofs severely stripped; mobile homes overturned or badly damaged; loss of exterior doors; windows and other glass broken.
F2	118-161	EF2	111-135	<b>Considerable damage.</b> Roofs torn off well-constructed houses; foundations of frame homes shifted; mobile homes completely destroyed; large trees snapped or uprooted; light-object missiles generated; cars lifted off the ground.
F3	162-209	EF3	136-165	<b>Severe damage.</b> Entire stories of well-constructed houses destroyed; severe damage to large buildings such as shopping malls; trains overturned; trees debarked; heavy cars lifted off the ground and thrown; structures with weak foundations are badly damaged.
F4	210-261	EF4	166-200	<b>Extreme damage.</b> Well-constructed and whole framed houses completely leveled; cars and other large objects thrown and small missiles generated.
F5	262-317	EF5	>200	<b>Total Destruction of Buildings.</b> Strong-framed, well-built houses leveled off foundations are swept away; steel-reinforced concrete structures are critically damaged; tall buildings collapse or have severe structural deformations; some cars, trucks, and train cars can be thrown approximately one mile.



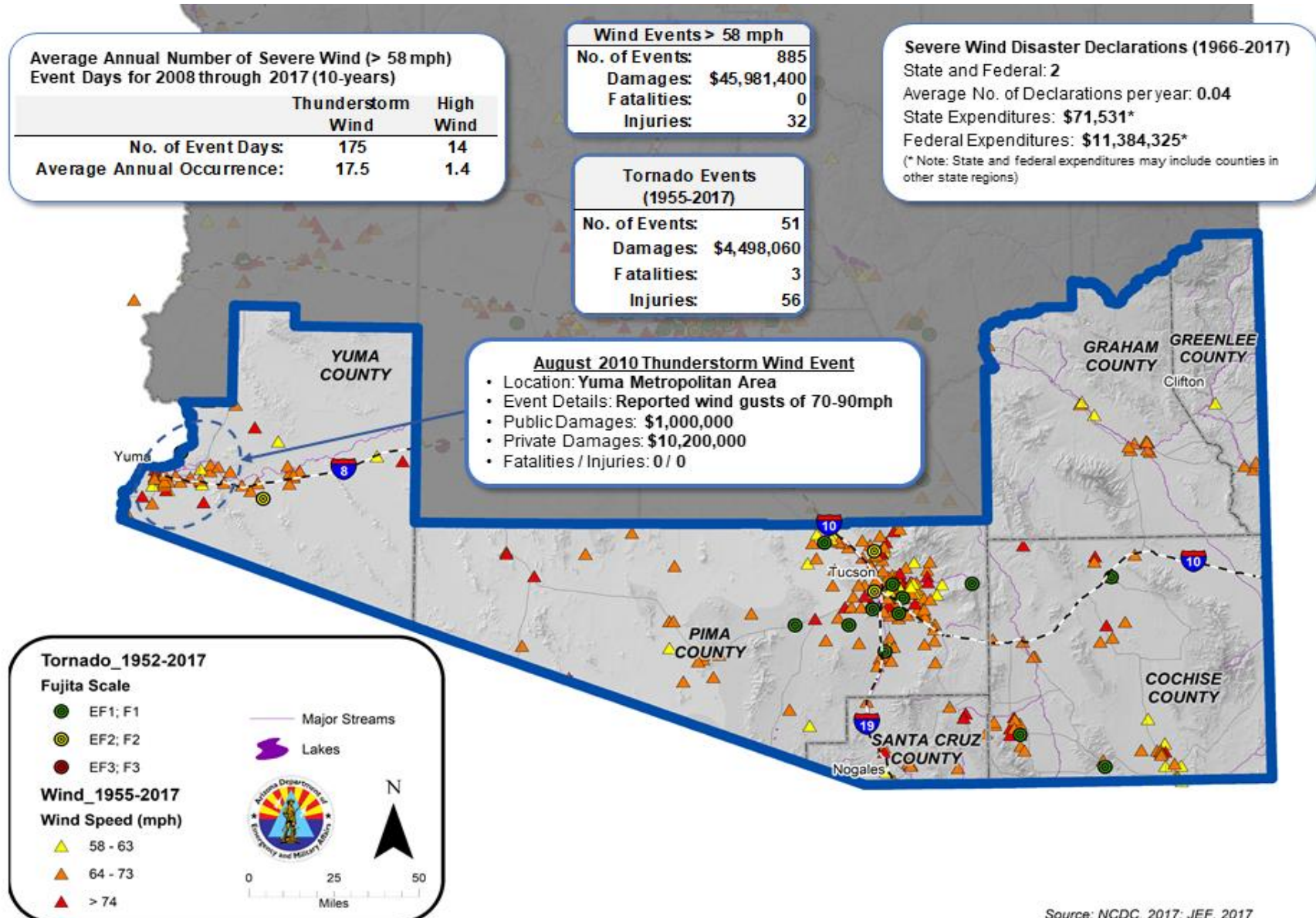
Map 37: Severe Wind Hazard for North Region





Map 38: Severe Wind Hazard for Central Region



**Map 39: Severe Wind Hazard for South Region**

## **WARNING TIME**

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Warning time with severe wind events associated with thunderstorms, including tornadoes, is usually measure in hours, with warnings being issued by the nearest NWS office. Spring-time winds are generally associated with regional atmospheric conditions that can be forecasted in hours or days.

## **FUTURE CONDITIONS**

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### **Climate Considerations**

The study by Luong (Luong, et al., 2015), notes that monsoon thunderstorms in the Central and Southern Regions of the state have become more intense over a recent 20-year period (1991-2010) when compared to events recorded in the past (1950-1970). The study concludes that the trend will likely continue as the temperatures rise and provide more moisture storage capacity in the lower atmosphere. The increased thunderstorm intensities may correlate to increased wind intensities, and especially if the thunderstorm cells are stronger and larger.

### **Changes in Development**

Development and population increases in all areas of the state will increase the exposure and risk associated with severe wind events. It is likely that most of the development and growth will be located near urbanized metropolitan areas.

## **VULNERABILITY ASSESSMENT**

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As demonstrated by the hazard maps, the entire state is assumed to be equally exposed to severe wind hazards where wind gusts may exceed 58 mph. The risk of damages or injury is greatest in the more populated urban areas due to the higher density of human and structural assets exposed. On average, individual incidents are fairly localized, and damages associated with individual events are relatively small. Extreme events, such as the July 2006 storm in the Phoenix Metropolitan area, can generate significant losses when they intersect with urbanized areas.

Damages to state-owned facilities are difficult to estimate without more detailed data on individual building type, construction material, and building size. According to the technical documentation for the wind loss component of the hurricane module of the HAZUS MH program, annualized building losses for wind gust speeds generally less than 90 mph, are reported as negligible (FEMA, 2009). In the entire record of events for Arizona, only two wind and three tornado records indicate 90 mph or more wind gusts. Accordingly, the expected annual losses to state-owned facilities are negligible. No severe wind-related losses are estimated for state-owned facilities.

There are also no local county risk assessments that provide any loss estimations to locally identified critical and non-critical facilities.

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## North Region

The North Region is the least vulnerable region of the state, primarily due to the limited density of structures and people when compared to the other regions. However, the North Region does have the most non-thunderstorm related severe wind events and tornadoes.

### State-Owned CFI Exposure and Loss Estimates

All 1,988 state-owned facilities representing \$2.4 billion in replacement value are exposed to a severe wind event. No losses are estimated.

### Vulnerable Population Groups

The entire 2015 estimated population of 772,157 people are considered to be equally exposed to severe wind events. This includes all of the sub-population groups of under 18-years of age, older than 65, poverty level, and LEP.

### Local Jurisdiction Vulnerability

None of the local jurisdictions in the North Region estimated losses for locally identified critical and non-critical facilities. All assumed that local facilities and populations were equally exposed.

### Specific Areas of Concern

Severe wind events along I-40 have been documented to blow tractor-trailer and recreational vehicle rigs off of the road. Formulation of tornadoes is a fairly rare occurrence, and as such, it is estimated that much of the public are not aware of what to look for as warning signs of an impending tornado. Sustained high wind events associated with spring in the North Region can turn loose building materials, trash, and small tree limbs into airborne projectiles that can cause structure damage and pose a safety threat.

## Central Region

The Central Region is considered to be the most vulnerable region in the state, largely due to the high risk associated with the density of structures and people in the Phoenix Metropolitan Area.

### State-Owned CFI Exposure and Loss Estimates

All 3,464 state-owned facilities representing \$9 billion in replacement value are exposed to a severe wind event. No losses are estimated.

### Vulnerable Population Groups

The entire 2015 estimated population of 4,604,414 people are considered to be equally exposed to severe wind events. This includes all of the sub-population groups of under 18 years of age, older than 65, poverty level, and LEP.

### Local Jurisdiction Vulnerability

None of the local jurisdictions in the Central Region estimated losses for locally identified critical and non-critical facilities. All assumed that local facilities and populations were equally exposed.

### Specific Areas of Concern

Dust storms generated by strong winds create a unique hazard and vulnerability to vehicular traffic traveling the interstates and highways of the region, as well as health risks to people with respiratory illness or other intolerance to airborne particulates. Visibility during a dust storm can be reduced to tens of feet, which when combined with the normal highway speeds, creates a recipe for severe and often fatal, multi-vehicle accidents. The areas of most vulnerability lay along Interstates 8, 10, and 17, as well as the metro area freeways (Loops 101, 202, and 303, US 60, and SR 51). Another area of particular concern relates to downed power lines in urbanized areas that have the potential to kill or seriously injure anyone that might come in contact with the lines.

### South Region

The South Region is considered to be the second most vulnerable region in the state, largely due to the high risk associated with the density of structures and people in the Tucson Metropolitan Area.

#### State-Owned CFI Exposure and Loss Estimates

All 1,505 state-owned facilities representing \$5.2 billion in replacement value are exposed to a severe wind event. No losses are estimated.

#### Vulnerable Population Groups

The entire 2015 estimated population of 1,458,367 people are considered to be equally exposed to severe wind events. This includes all of the sub-population groups of under 18-years of age, older than 65, poverty level, and LEP.

#### Local Jurisdiction Vulnerability

None of the local jurisdictions in the North Region estimated losses for locally identified critical and non-critical facilities. All assumed that local facilities and populations were equally exposed.



Fatal Dust Storm Accident on I-10 in Eastern Cochise County  
Source: USA Today

### Specific Areas of Concern

Similar to the Central Region, dust storms present a unique hazard and vulnerability to vehicular traffic traveling the interstates and highways of the region, as well as health risks to people with respiratory illness or other intolerance to airborne particulates. The areas of most vulnerability lie along Interstates 8, 10 and 19. The eastern stretch of I-10 in Cochise County near the New Mexico border has repeatedly been impacted, resulting in several fatalities and numerous injuries. Exposure to downed power lines in the urbanized areas is prevalent in this region as well.



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## POTENTIAL CONSEQUENCES AND IMPACTS

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### Public

Severe winds can cause property destruction and the disruption of services such as power. Members of the public, such as motorists, air travelers, outdoor workers and those who participate in outdoor recreation, may also be impacted by wind events that result in falling trees, poles, debris, or collapsing structures. Loss of power from downed power lines may also impact the already vulnerable public who are hospitalized, convalescent and citizens dependent on home medical equipment. Power loss during summer monsoon events will also impact citizens in general who depend on air conditioning to mitigate the risks of heat stress. Blowing dust and particulates can also pose an increased health risk to people with respiratory conditions and weakness.

### Property/Facilities/Infrastructure

Mobile homes, ancillary sheds, awnings, and poorly constructed buildings are most vulnerable to damage during a severe wind event. Older, wooden power poles are also vulnerable to severe winds. Most other buildings constructed using modern building codes and practices are less vulnerable. Other damages to property include trees, landscape, fencing, and other peripheral features. Extremely strong winds can break glass and do moderate damage to well-constructed buildings, as well as create projectiles from building materials, poles, signs, trash, and other loose material.

### Responders

Law enforcement and public safety personnel may be impacted as they perform their duties in response to a severe wind event such as a dust storm accident, downed power lines, or trees that fall in the roadway during a storm event. Tornado events cause a greater chance of injury, illness, or death for first responders as they put themselves in harm's way to perform their duties and rescues. Responders may have to work extended shifts during emergency and rescue duties, so exhaustion could also be considered as a factor.

### Continuity of Operations/Delivery of Services

Severe wind events may impact the use of public roadways or disrupt power in localized areas. While public facilities may remain usable during an event, the wind event may impact the effectiveness of public service delivery if facilities are damaged, or roads become impassable. Facilities without a backup power supply may be unable to provide services during a power interruption. Extreme wind events may cause enough damage to government buildings to require relocation of services to alternate location or closure until repairs can be made. Other services at the local level that may be impacted include water delivery and wastewater treatment if severe wind events damage power facilities and no backup power is available.

### Environment/Cultural

Severe wind events have the potential to cause damages that are detrimental to the environment. Truck and railroad accidents caused by severe winds may result in the release of hazardous materials. Damages to structures housing hazardous materials can also cause unintended

releases. Tree loss and damages to agricultural crops can also result. Severe wind-related damages to culturally significant buildings can result in displaced congregations or patrons.

### **Economic/Financial Condition of Jurisdiction**

Although significant, most severe wind event based damages are not of a magnitude to jeopardize the financial condition or economy of a community. Often losses are insured, and contractors are able to respond and make repairs in a timely manner. Businesses sustaining significant damages may suffer additional costs due to lost business revenue during recovery or loss of inventory. Loss of businesses further affects the jurisdictions by the loss of tax revenue as well as local employment. Seasonal businesses can be especially impacted if damages occur at the height of their business season.

### **Public Confidence in Jurisdiction's Governance**

Arizona's emergency response agencies typically have sufficient capacity to respond to severe wind events promptly and efficiently. The public has high expectations for government warning, information, response, and recovery. Emergency operations centers will be activated as needed to coordinate these activities. Most severe wind events are short in duration, and in most cases, the community will be restored to pre-event status within hours at best and days at worst. The ability to perform effective governance is seldom an issue with severe wind events.

### **Cascading/Secondary Impacts**

The most common secondary effect of severe wind events is power outages from downed power lines and traffic accidents from blowing dust. Significant power outages that occur during a typical monsoon season can also lead to extended periods of no air conditioning and refrigeration, leaving many people at risk for heat-related illness and food loss. Dust storms and/or sand storms reducing visibility on interstates and highways can cause challenging conditions for the traveling public and commerce trucking.

## **RESOURCES**

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### **Sources**

National Climate Data Center, Storm Event Database, <http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwevent~storms#NOTICE>

NOAA Storm Prediction Center Events Archive, <http://www.spc.noaa.gov/wcm/index.html#data>  
Spatial Hazard Events and Losses Database for the United States, <http://webra.cas.sc.edu/hvri/products/sheldus.aspx>

### **References**

American Society of Civil Engineers, 1999, ASCE 7-98: *Minimum Design Loads for Buildings and Other Structures*.

Coconino County, 2015, *Coconino County Multi-Jurisdictional Hazard Mitigation Plan*.

FEMA, July 2000, *Design and Construction Guidance for Community Shelters* (FEMA 361), <http://www.fema.gov/fima/fema361.shtm>

FEMA, August 2009, *Multi-Hazard Loss Estimation Methodology, Hurricane Model*, HAZUS MH-MR4, User Manual.

NOAA National Centers for Environmental Information, US Tornado Climatology, 2017, <https://www.ncdc.noaa.gov/climate-information/extreme-events/us-tornado-climatology>

## SUBSIDENCE

Subsidence occurs when the established land surface elevation lowers due to changes in the subsurface. Causes of subsidence include, but are not limited to, removal or reduction of fluids (water, oil, gas, etc.), mine subsidence, and hydro compaction. Of these causes, hydro compaction and mine subsidence tend to be localized events, while fluid removal may occur either locally or regionally. Land subsidence in the basins of Arizona is generally due to compaction of the alluvium caused by lowering of the groundwater table. As the water table declines, pores in the alluvium once held open by water pressure are no longer supported and collapse. Collapse and



Subsidence at well casings  
Source: AZGS



subsequent lowering in elevation of the land surface is defined as land subsidence. This subsidence is generally not recoverable. If this subsidence occurs over areas of bedrock, differential subsidence can occur. Once an area has subsided, the ground elevation will often not rise again due to consolidation of the soils within the aquifer, even if the removed fluid is replaced.

Subsidence can result in altered regional drainage patterns, indirectly affecting surface flooding, storm drain flow, and damaging infrastructure both in the subsurface (water and electric lines, well casings, etc.) and surface (roads, canals, drainages, surveyed benchmarks, etc.). It aggravates riverine flooding, alters topographic gradients, and ruptures the land surface in addition to causing other hazards related to deterioration of land and water resources. Earth fissures are caused by differential land subsidence and are often found along the margins of subsiding areas.

## HISTORY

There are no state or federal disaster declarations for subsidence occurrences for Arizona. Land subsidence, however, has been occurring in Arizona since the early 1920s, with the greatest activity occurring post-1945. The following are descriptions of losses or damages with direct connection to local subsidence.

- Central Arizona Project (CAP) Canal Pools 23 and 24 - Freeboard loss was first detected in north Scottsdale near the Via Linda Road Bridge in June 1999. Approximately 1.4 feet of subsidence occurred in this area raising the water level to within a few inches of the top of the canal lining. In response, CAP raised the canal lining three feet over a one-mile segment of affected area at a cost of \$350,000. A second and much larger subsidence area was later identified near the Scottsdale Airpark. This elongated subsidence area extends



northwest into Phoenix and up to 1.2 feet of subsidence has occurred near the Scottsdale Road Bridge. The canal lining was raised in this area at an estimated cost of \$820,000. Recently, a third subsidence area has been identified east of the Scottsdale Airpark (CAP, 2007).

- Luke Air Force Base – Land subsidence of up to 20 feet has been measured in the area around Luke Air Force Base over the last 60-years. The



CAP Canal lining raise in Pool 24  
Source: Central Arizona Project

gradient, or slope, and corresponding capacity of the Dysart Drain, which is a major flood-control channel along the north side of the base, was significantly reduced by differential land subsidence. On September 20, 1992, a high-intensity storm produced about four inches of rain immediately north of the base which resulted in extensive flooding on the base. Floodwater overtopped the Dysart Drain and spilled onto the runways, into the aircraft parking areas, and into the base-housing area. The flooding closed the base for three days, inundated more than 100 homes, and generally disrupted base operations. Preliminary estimates of flood damage exceeded \$3 million (Cook, 2013). Redesign and reconstruction of the Dysart Drain system to correct for the land subsidence was estimated to exceed \$16 million (Schumann and O'Day, 1995).

- Paradise Valley – Subsidence of up to five feet has occurred in the area generally bounded by Bell Road on the north, Scottsdale Road on the east, Shea Boulevard on the south and 36<sup>th</sup> Street on the west, during the period of 1960-1980. At 56<sup>th</sup> Street and Mountain View, excessive sewage gases were produced in a city sewer main due to slope change and a significant reduction in the system's capacity to self-clean. Expensive chemical feeder countermeasures were needed to mitigate the gas production and other sewer mains in the area are also vulnerable. The subsidence also caused the collapse of a municipal well casing and the need to re-establish local vertical survey benchmarks (Harmon, 1982).

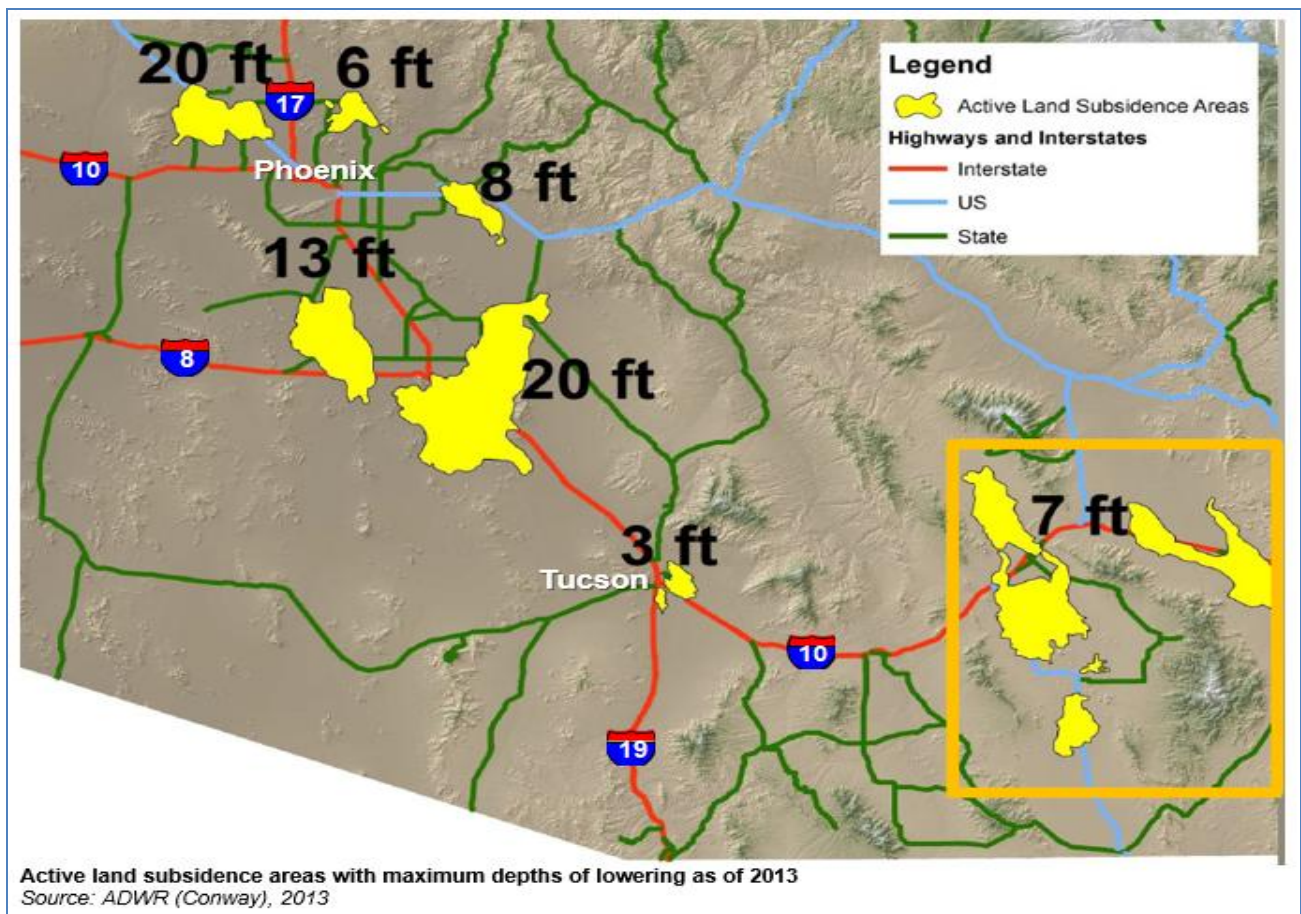
## PROBABILITY/EXTENT

The probability of subsidence occurring in the state is high at 100%, with occurrences generally being located in southern part of the state situated in the Basin and Range Province. Since 1900, the south-central Arizona's groundwater pumping for irrigation, mining, and municipal use has outpaced the recharge by 500 times in some areas (Schumann and Cripe, 1986). Over 3,000 square miles of the state is affected by subsidence, including the surrounding and expanding areas of the Phoenix and Tucson Metropolitan areas, and the rapidly growing areas of northern Pinal County. Before many communities became established, agriculture was the driving force for groundwater pumping. In Arizona, groundwater accounts for 40% of all water use (ALSG, 2007).

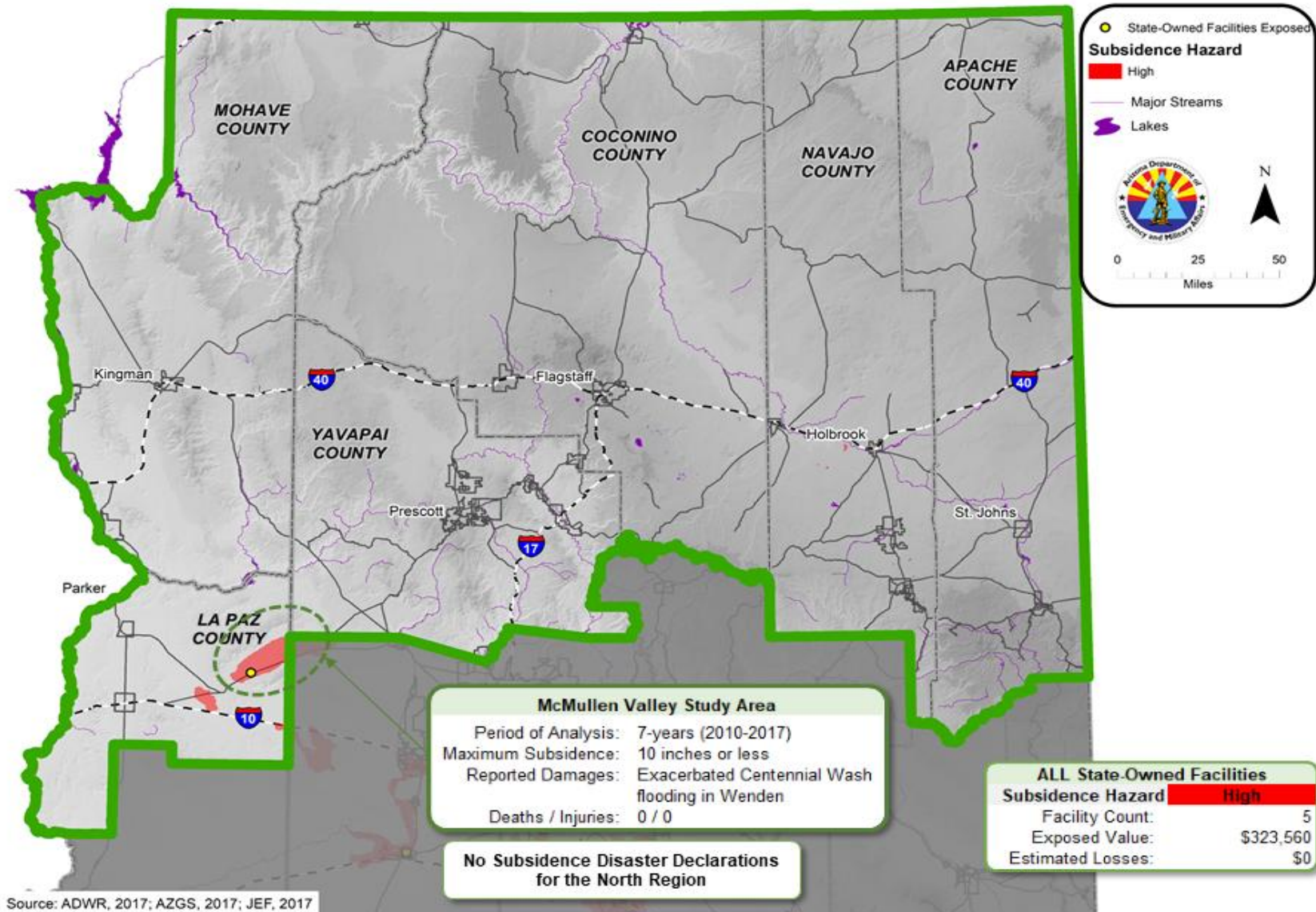
Land subsidence in Arizona correlates closely with groundwater level declines associated with overdraft of the state's aquifers. According to the USGS (Galloway, et.al., 1999), groundwater pumping prior to 1980 was responsible for water levels declines of up to 400 feet. Map 40 is developed by Arizona Department of Water Resources (ADWR) that generally illustrates the historic to-date maximum subsidence amounts for the active areas currently identified in the state.

The magnitude of a land subsidence event is low due to the fact that subsidence is unlikely to cause sudden wide spread damage to life and infrastructure. Subsidence has been detected over the years using surveying techniques such as differential leveling and high accuracy Global Navigation Satellite System (GNSS) surveying. In the early 1990's, scientists began to use satellite-based radar technology called Interferometric Synthetic Aperture Radar (InSAR) to detect land surface elevation changes. InSAR has been developed into a highly reliable land subsidence monitoring technique that can potentially measure centimeter-scale changes in deformation over timespans of days to years. InSAR has been successfully utilized by the ADWR since 2002, and is especially effective for areas that do not undergo mechanical surface alterations on a regular basis. For the purpose of this Plan, the active subsidence areas are considered by the Planning Team to be high hazard areas.

**Map 40: Subsidence Maximum Depths Statewide**

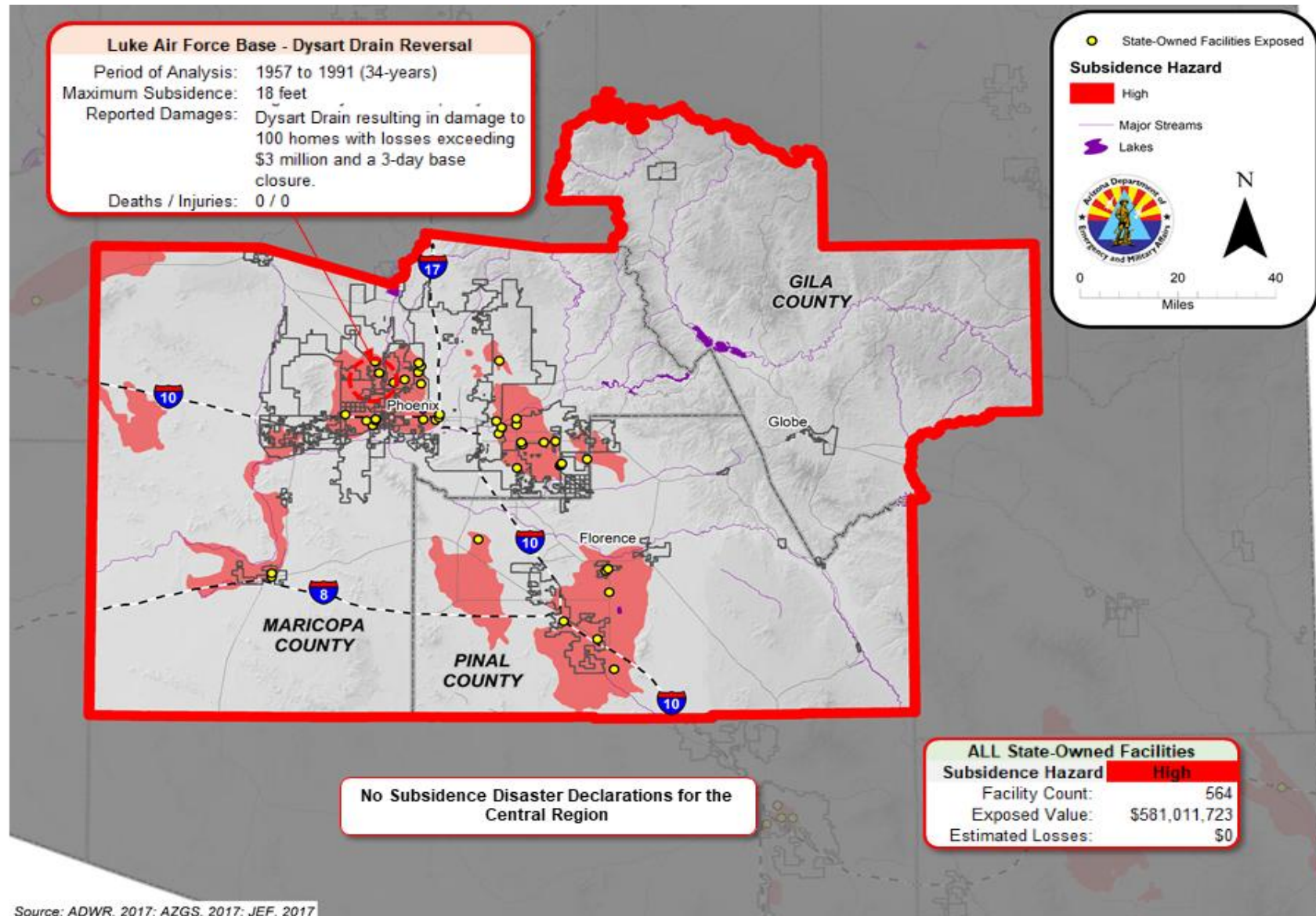




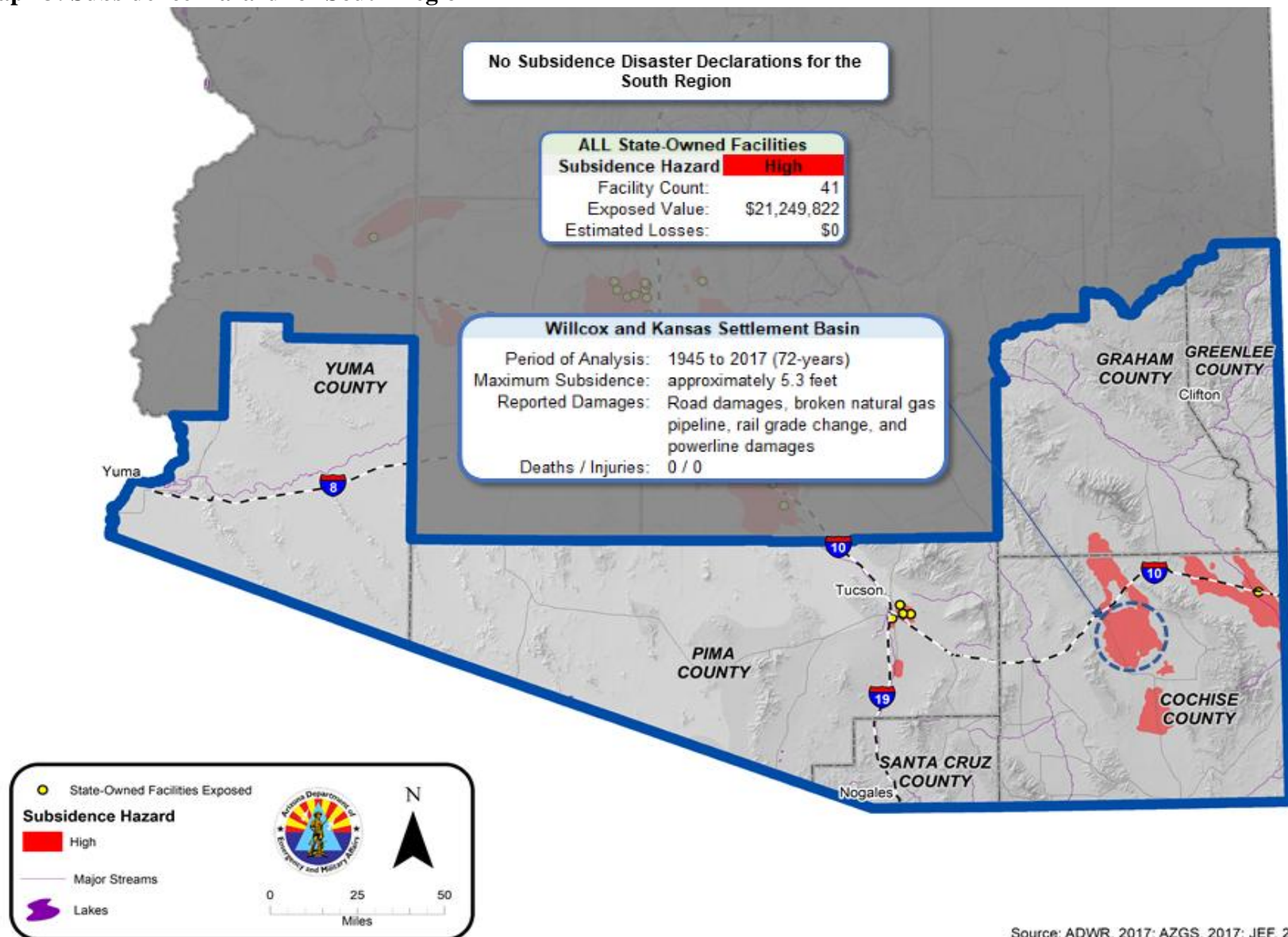


**Map 41: Subsidence Hazard for North Region**

## Map 42: Subsidence Hazard for Central Region





**Map 43: Subsidence Hazard for South Region**

## WARNING TIME

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The process of land subsidence is gradual, and the lowering of the land surface occurs almost imperceptibly and over the course of many years. Accordingly, warning time is not relevant to subsidence and especially not in the way of emergency response or prediction. Changes or initiation of subsidence can be effectively monitored and evaluated using current survey and InSAR tools.

## FUTURE CONDITIONS

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### Climate Considerations

Arizona subsidence is primarily the result of groundwater depletion, and climate change factors increase the use of groundwater and effect changes to the recharge of aquifers. The projected long-term worsening or intensifying of drought periods through warming trends and precipitation influences may also have the effect of increasing the rate of subsidence if groundwater sources continue to be depleted. The Arizona Land Subsidence Group (2007) states: *“The problems encountered with subsidence and earth fissures in Arizona will increase as groundwater continues to be withdrawn at unsustainable levels. More damage to structures and infrastructure can be expected with ever increasing economic losses, and, more importantly, a burgeoning threat to human health and safety, too.”* The effects of reduced recharge would be especially impacting to areas outside of the area serviced by the Central Arizona Project or Salt River Project, since there are no alternative sources for implementing groundwater recharge when local resources are in decline.

### Changes in Development

Development and the population continue to grow in areas that are subjected to the risks of fissure formation as old agricultural lands are converted to residential housing units. Increased water demand from new developments, combined with limited surface-water supplies, induce increased groundwater pumping that exacerbates fissure formation conditions.

#### North Region

Except for a small portion of La Paz County, most of the North Region has very low to no risk from subsidence. Accordingly, development changes in the non-La Paz County areas of the North Region are not expected to be impacted by subsidence risk.

The active Ranegras Plain and McMullen Valley subsidence areas in La Paz County are not anticipated to experience significant population growth over the next five years. Local agriculture relies solely on groundwater for meeting the irrigation needs of the local farms, so proposed changes to crop types or irrigation methods that increase the water demand may increase the groundwater declines and exacerbate the current subsidence rates.

#### Central Region

Areas within the Central Region have experienced the most significant subsidence in the state. Development of the Phoenix Metropolitan communities (both the west and east

valley), and the San Tan Valley, are expected to continue, and will likely be impacted by ongoing subsidence rates. Impacts to drainage and gravity flow systems may require special design considerations in the areas of significant lowering. Conversion of agricultural lands to residential, commercial, and industrial developments may initially reduce the burden on groundwater sources as irrigated agriculture typically uses more water, allowing for wastewater streams to be treated and recharged. Expansion of development in the higher risk Casa Grande, Eloy, and Picacho areas is expected to be limited over the next five years.

### South Region

The primary areas of active subsidence are located near the Tucson Metropolitan area and the Willcox, San Simon, Bowie, and Elfrida areas of Cochise County. Moderate growth of the Tucson Metropolitan area is anticipated and may be impacted by slight subsidence. Recent InSAR data indicate that the Tucson area subsidence rates are very low; however, these trends could reverse if extra burden is placed on the existing groundwater supplies to meet growth demands. Very limited growth of the Cochise County areas is anticipated, and some of that growth may extend into the active subsidence areas.

## VULNERABILITY ASSESSMENT

Most of the significant damages associated with subsidence are typically related to the secondary, causal effects of subsidence as it relates to altering surficial profiles and slopes, and fissure development. Directly attributable impacts and damages may include:

- Uneven or differential subsidence across large agricultural fields requiring expensive re-leveling efforts and irrigation system reconfiguration.
- Well damage and protruding well casings in both agricultural and urban areas.
- Replacement or remediation of large, regional, gravity-based drainage, irrigation and wastewater systems due to flow reversal or changes of slope.
- Loss of municipal benchmark network accuracy and the need to re-survey and re-establish vertical bench mark elevations

The estimation of potential exposure to the identified high subsidence hazard zones was accomplished using GIS tools to intersect the human and state-owned regular and critical facilities and infrastructure (CFI) data with the subsidence hazard limits depicted on profile maps. Except for fissure generation, subsidence activity generally does not create direct losses to structures and buildings; therefore, no quantitative losses to state-owned facilities are made, and only exposure quantities will be reported for state-owned assets. Exposure estimates of the various population sectors to high subsidence hazard zones are also made.

There are only two counties (Maricopa and Pinal) that included subsidence as a significant hazard in their local county risk assessments.

### North Region

Apart from the McMullen Valley in western La Paz County, North Region vulnerabilities to subsidence are very low. The North Region is the least vulnerable region of the state, primarily due to the lack of identified subsidence zones, and very few assets and population at risk.

### State-Owned CFI Exposure and Loss Estimates

A total of four state-owned CFI, or 1.4% of the statewide exposure, are located within a high hazard area. The exposed facilities represent a total replacement value of \$204,029. No losses are estimated.

Additional state-owned facilities vulnerable to subsidence are the ADOT operated and maintained roads that pass through the known subsidence hazard areas. For example, US Hwy 60 parallels and then crosses Centennial Wash near Wenden. Subsidence in the McMullen Valley area is believed to exacerbate flooding in Centennial Wash due to lowering of the wash and flattening of the watercourse slopes. The bridge crossing at Hwy 60 may be downgraded in hydraulic safety considerations due to continued lowering and may require replacement to maintain design standards. Costs would likely be in the millions of dollars.

### Vulnerable Population Groups

The 2015 estimated total population for the North Region is 772,157 people. Approximately 0.15% of the total population, or 1,168 persons, are located within the high subsidence hazard areas.

On average, approximately 7.3% of the North Region population is estimated to have a Limited English Proficiency (LEP). Assuming the percentage is equally applied across the whole region's population, roughly 86 LEP persons (6.7% of 1,168) are estimated to be located within the high subsidence hazard areas.

### Local Jurisdiction Vulnerability

None of the local jurisdictions in the North Region included subsidence in their risk assessments. Accordingly, there are no estimated quantitative subsidence related losses for locally identified critical and non-critical facilities.

### Specific Areas of Concern

Subsidence in the McMullen Valley Area is directly correlated with the pumping of irrigation water for agricultural purposes. According to ADWR (2009), the total groundwater drawn from the McMullen Valley aquifer is approximately 77 times the annual recharge capacity, which is unsustainable. Continued use of the valley's groundwater at a rate that exceeds the recharge capacity, will result in continued subsidence.

## Central Region

Central Region vulnerabilities to subsidence are moderately high. The Central Region is considered the most vulnerable region in the state, due to the largest number and size of identified active subsidence areas, significant population and infrastructure within the hazard areas, and exposure of population and state-owned facilities. From a benefit perspective, the availability of water via the CAP and SRP systems decrease the Central Region's reliance upon groundwater and hence, the rates of subsidence in several areas.



### State-Owned CFI Exposure and Loss Estimates

A total of 257 state-owned CFI, or 87.7% of the statewide exposure, are located within a high hazard area. The exposed facilities represent total replacement values of \$294.7 million. No losses are estimated.

Additional state-owned facilities vulnerable to subsidence are the ADOT operated and maintained freeways, highways, and state routes that pass through the known subsidence hazard areas. Alterations of ground elevations and slopes may have adverse consequences on drainage systems and cause unexpected flooding or ponding.

### Vulnerable Population Groups

The 2015 estimated population for the Central Region is 4,604,414 people. Approximately 42.34% of the total population, or 1,949,499 persons, are located within the high subsidence hazard areas. On average, approximately 6.7% of the Central Region population is estimated to have a Limited English Proficiency (LEP). Assuming the percentage is equally applied across the whole region's population, roughly 129,967 LEP persons (6.7% of 1,949,499) are estimated to be located within the high subsidence hazard areas.

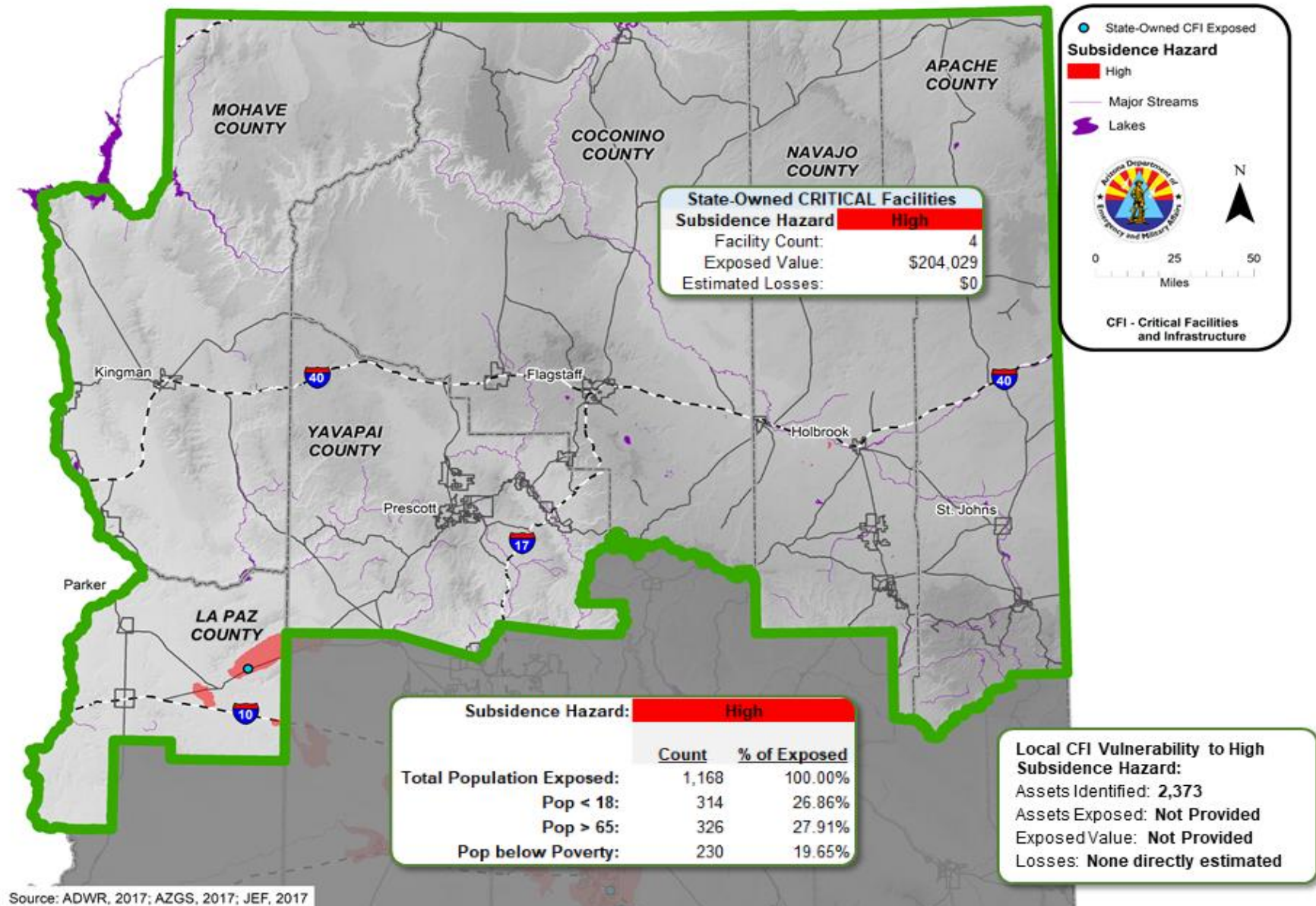
### Local Jurisdiction Vulnerability

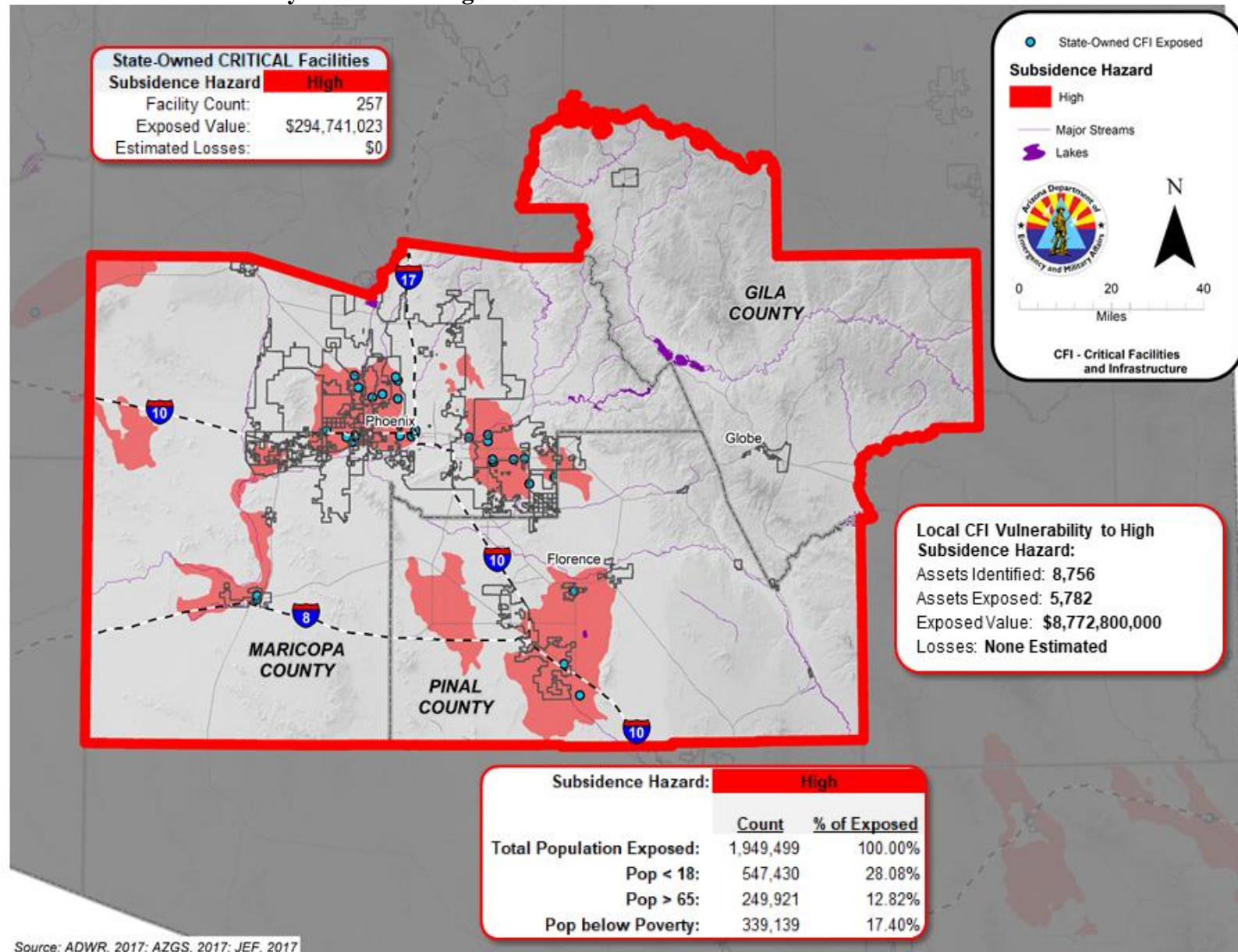
Maricopa and Pinal Counties included subsidence in their risk assessments and used a similar approach to define subsidence hazard zones. Between the two plans, a total of 5,782 assets with a total replacement value of \$8.77 billion have been identified to be located within a high hazard area. No losses to local CFI were estimated.

### Specific Areas of Concern

For many areas of the Central Region, subsidence rates have significantly reduced in the last 30 years due to alternative water supplies provided by the CAP and regulation of groundwater pumping through the Arizona Groundwater Management Act of 1980 creation of the Phoenix and Pinal Active Management Areas. Should CAP allocations be reduced due to shortages in the Colorado River, groundwater would become the only available replacement to meet the demands and the threat of water level declines would be elevated, re-activating pre-CAP rates of subsidence. It is also noted that subsidence continues to this day, and agencies and municipalities must continue to monitor and evaluate the rates of decline when considering development of large, regional, gravity-flow based infrastructure.

Map 44: Subsidence Vulnerability for North Region



**Map 45: Subsidence Vulnerability for Central Region**



## South Region

South Region vulnerabilities to high subsidence hazards are moderate. The region is the second-most vulnerable region in the state, largely due to the number and size of the active subsidence areas, the limited history of damages, and the smaller amount of population and facility exposure when compared to the Central Region.

### State-Owned CFI Exposure and Loss Estimates

A total of 32 state-owned CFI, or 10.9% of the statewide exposure, are located within a high hazard area. The exposed facilities represent total replacement values of \$18.6 million. No losses are estimated.

Additional state-owned facilities vulnerable to subsidence are the ADOT operated and maintained freeways, highways, and state routes that pass through the known subsidence hazard areas. Alterations of ground elevations and slopes may have adverse consequences on drainage systems and cause unexpected flooding or ponding.

### Vulnerable Population Groups

The 2015 estimated total population for the South Region is 1,458,367 people. Approximately 5.96% of the total population, or 86,866 persons, are located within the high subsidence hazard areas.

On average, approximately 12.7% of the South Region population is estimated to have a Limited English Proficiency (LEP). Assuming the percentage is equally applied across the whole region's population, roughly 11,003 LEP persons (12.7% of 86,866) are estimated to be located within the high subsidence hazard areas.

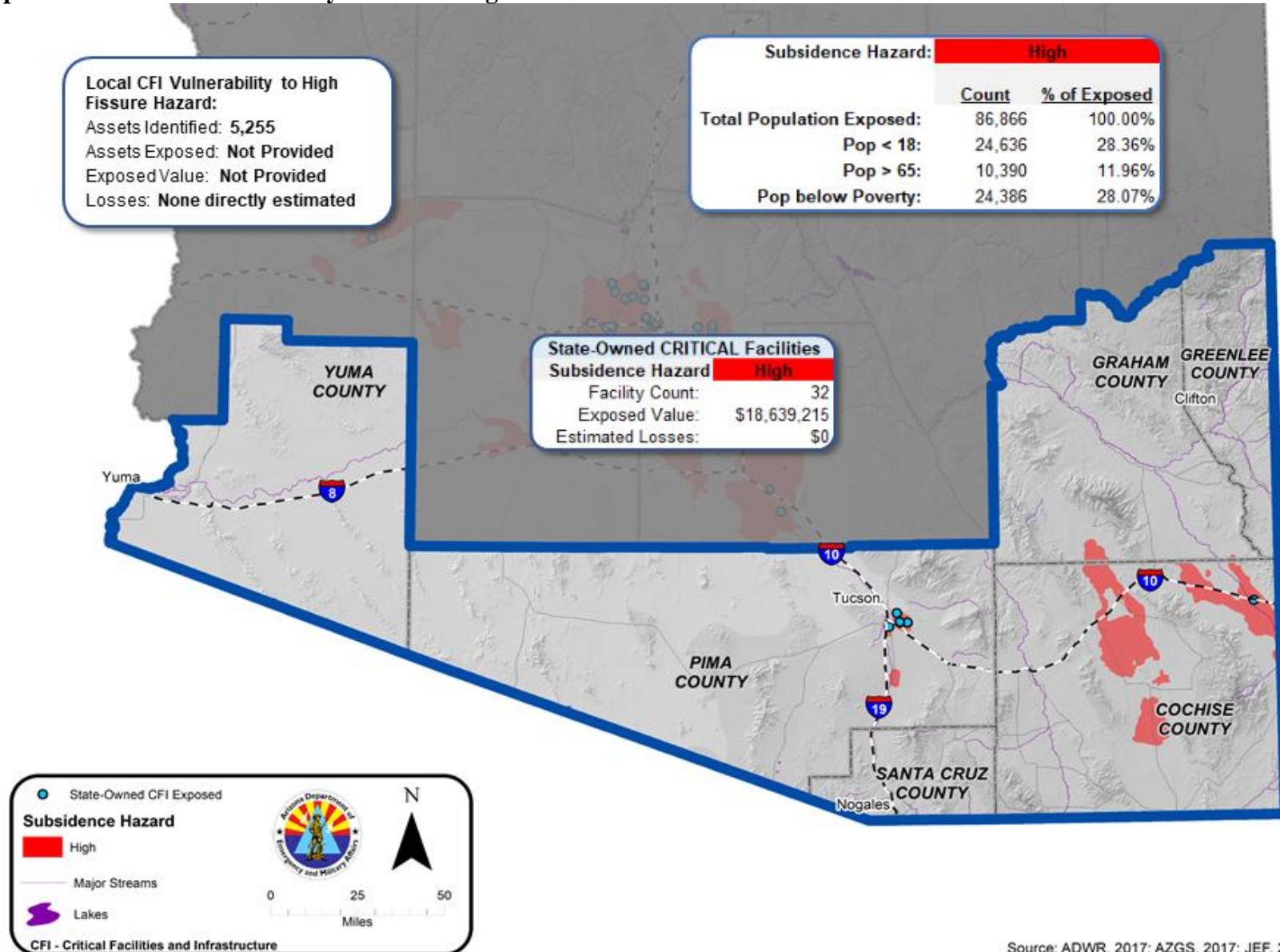
### Local Jurisdiction Vulnerability

None of the local jurisdictions in the South Region included subsidence in their risk assessments. Accordingly, there are no estimated quantitative subsidence related losses for locally identified critical facilities or infrastructure.

### Specific Areas of Concern

Alternative water sources for recharging groundwater in the active subsidence areas in Cochise and southern Pima Counties do not exist and groundwater basins in those areas are dependent on watershed generated surface water. In most cases, the groundwater withdrawal outpaces the recharge by a factor of 50-100 times, and ultimately is unsustainable.



**Map 46: Subsidence Vulnerability for South Region**

## **POTENTIAL CONSEQUENCES AND IMPACTS**

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### **Public**

Generally, subsidence in and of itself, does not pose a significant threat to the health and safety of the public. The real threats come with the indirect/secondary effects that are discussed later in this section.

### **Property/Facilities/Infrastructure**

Subsidence impacts the water delivery canals of the Central Arizona Project (CAP) as they require a slope to send water to different parts of the state. Subsidence can reduce the delivery capacity and safety features of the canals. Subsidence can also impact the effectiveness of flood control structures such as basins, channels, levees, and dams. Sewer line slopes can be reduced or even reversed causing the dangerous build-up sewer gases or deposition of solids in the pipe.

### **Responders**

The threat of subsidence to responders is negligible, and like the public, poses greater concern regarding the secondary/indirect impacts of fissure, flooding, etc.

### **Continuity of Operations/Delivery of Services**

Subsidence is not a threat to the state's ability to continue effectively functioning.

### **Environment/Cultural**

Due to the surface elevation drops associated with subsidence, the resulting environmental threat is associated with indirect/cascading impacts such as altered flooding patterns, potential groundwater contamination due to the entry of floodwaters directly into groundwater through fissures, etc.

### **Economic/Financial Condition of Jurisdiction**

Land subsidence will typically not cause great economic stress; however, it is often associated with other secondary impacts that may have significant economic consequences to a region. Causing flood-prone areas, backing up storm drains and sanitary sewers, lowering dam and levee profiles, and generating fissures are all examples. Re-leveling of agricultural fields to compensate for elevation changes or remediation of irrigation delivery systems can be costly and ultimately translate into increased product costs. Errant benchmarks that have been altered by subsidence can be extremely costly in surveying and engineering of new developments and facilities, both at the design phase and construction. Remediation or reconstruction of gravity sewer lines can be very costly and especially if they are located in utility congested municipal streets and rights-of-way.

### **Public Confidence in Jurisdiction's Governance**

In general, the public's confidence in the state's ability to govern is not affected by subsidence. Manifestation of unexpected secondary impacts such as altered flooding or fissures may erode the public's confidence in the local jurisdiction's ability to mitigate damages.

## Cascading/Secondary Impacts

Potential secondary or cascading events associated with subsidence, include:

- Gradient changes in drainage leading to localized flooding and ponding of flood waters;
- Gradient changes leading to negative effects on gravity flow water and sewer systems;
- Tilting of agricultural fields requiring expensive re-leveling and potentially reconfiguration of irrigation headworks;
- Reduced freeboard of levees and dams leading to insufficient freeboard capacity, overtopping, and potentially catastrophic breach conditions;
- Formation of earth fissures and their attendant damage potential;
- Infrastructure damage – notably to roads, railroads, earthen dams, and water and sewer systems;
- Damaged water casing and disrupted well heads, which could result in broken piping impacting water delivery and quality.

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## **TERRORISM**

The term “terrorism” refers to intentional, criminal, malicious acts, but the functional definition of terrorism can be interpreted in many ways. Officially, terrorism is defined in the Code of Federal Regulations as “...the unlawful use of force and violence against persons or property to intimidate or coerce a government, the civilian population, or any segment thereof, in furtherance of political or social objectives” (28 CFR §0.85). Terrorists use threats to create fear, in an attempt to convince citizens of the powerlessness of their government, and to get publicity for their cause.

Terrorist attacks can take many forms, including agroterrorism, arson/incendiary attack, armed attack, assassination, biological agent, chemical agent, cyberterrorism, conventional bomb, hijackings, intentional hazardous material release, kidnapping, nuclear bomb, and radiological agent (FEMA April 2009). Terrorists can utilize almost anything to carry out an attack, including less complex methods such as firearms, small homemade explosive devices, and vehicles to strike crowds of people. There are many avenues terrorist actors can use to cause harm, but the most concerning for Arizona are chemical, biological, radiological, nuclear, or cyber attacks.

### **Chemical**

Chemical weapons utilize an agent that causes toxicity: that is, their chemical reaction can cause death, permanent harm, or temporary incapacity. Chemical weapons come in many forms, including cyanides, mustard agents, nerve agents, and toxic industrial chemicals.

### **Biological**

Biological weapons infect people with disease-causing microorganisms and pathogens like viruses, bacteria, and fungi. Biological agents have the ability to multiply in hosts over time. Key characteristics of an ideal biological agent are infectivity, virulence, lethality, pathogenicity, incubation period, contagiousness, and stability; all resulting in widespread infection, illness, and death. Some of the most concerning biological agents are anthrax, botulinum toxin, and ricin. Biological agents do not just affect people, but can have severe adverse effects on livestock and crops. Some biological agents cannot be easily detected and may take time to develop. Therefore, it can be difficult to know that a biological attack has occurred until victims display symptoms. In other cases, the effects are immediate.

### **Radiological**

Radiological weapons expose the population to radioactive material. This can be accomplished through the use of a “dirty bomb” or radiological dispersal device (RDD), radiological exposure device (RED), or by sabotaging a nuclear power plant. Radiological attacks are not likely to cause catastrophic death and injury but may cause both short and long-term health problems for those exposed.

### **Nuclear**

Nuclear weapons that may be utilized by terrorists are often characterized as improvised nuclear devices (IND). An IND gives off four types of energy: blast wave, intense light, heat, and radiation. Nuclear fallout develops as dust-like particles from the explosion drop to the earth and contaminate all surfaces with radioactive material.

## Cyber

Cyberterrorism has become a large threat in recent years. Cyberterrorism is defined as activities intended to damage or disrupt vital computer systems. These acts can range from taking control of a host website to using networked resources to directly cause destruction and harm. Cyber terrorists can be difficult to identify because the internet provides a meeting place for individuals from various parts of the world. Individuals or groups planning a cyber-attack are not organized traditionally, as they can effectively communicate over long distances without delay. The largest threat to institutions from cyber terrorism comes from any processes that are networked and controlled via computer.

## International Terrorism

International terrorism is perpetrated by individuals and/or groups inspired by or associated with designated foreign terrorist organizations or nations. The Islamic State of Iraq and Syria (ISIS) is the most potent international terrorist threat, but Al-Qa'da and Hezbollah continue to threaten the US homeland. Recruitment of violent extremists through social media is central to ISIS's terrorist campaign.

## Domestic Terrorism

Domestic terrorism is perpetrated by individuals and/or groups inspired by or associated with primarily U.S.-based movements that espouse extremist ideologies of a political, religious, social, racial, or environmental nature.

## HISTORY

On the day following the September 11, 2001 attacks, the state declared its first and only terrorism emergency. Prior to and since that time, there have not been any major terrorism attacks in Arizona. National and international events are examples of terrorist attacks that may occur in Arizona. The following major attacks represent national and international examples that have occurred or were narrowly avoided in the last 10-years:

- Orlando Pulse Nightclub Shooting, 2016 - Omar Mir Seddique Mateen, 29, armed with a rifle and a handgun, began shooting patrons inside Pulse nightclub in Orlando, Florida. Law enforcement officers entered the nightclub and engaged the shooter, the shooter then barricaded himself inside a bathroom with hostages for approximately three hours. Forty-nine people were killed; 53 were wounded. The shooter was killed in an exchange of gunfire with law enforcement officers after they breached the building. The FBI asserted his possible link to radical Islam.
- Boston Marathon Bombing, 2013 - At least three were killed and over 170 injured when two bombs sent shrapnel into the crowd and runners' paths. Pieces of metal flew out at leg level, leading to a number of severe leg injuries.
- Times Square Car Bombing Attempt, 2010 - Faisal Shahzad ignited an explosive in



Times Square. The bomb failed to go off, and he was later arrested on a flight leaving for Dubai. He was sentenced to life in prison on October 5, 2010 after pleading guilty to a 10-count indictment in June, including attempting to use a weapon of mass destruction.

Recent notable cyber terrorism incidents include:

- Ferizi US Military Identity Hack, 2015 – In June 2015, Ardit Ferizi, operating as part of the hacking crew known as the Kosova Hacker’s Security, hacked into a server used by an un-named Illinois-based online retail company and accessed data on about 100,000 people. Ferizi chose his target with the specific intent to gather information on US military personnel. He parsed the stolen data, discovering personal information of about 1,351 military and other government personnel, and provided the information to ISIS/ISIL in the form of a “kill list”. Ferizi was captured by US authorities and is the first terrorist hacker to be convicted in the US – serving a 20-year sentence.<sup>1</sup>
- Media Attack by Syrian Electronic Army, 2013 - In August 2013, media companies including the New York Times, Twitter, and the Huffington Post lost control of some of their websites after hackers supporting the Syrian government breached the Australian internet company that manages many major site addresses. The Syrian Electronic Army, a hacker group that has previously attacked media organizations that it considers hostile to the regime of Syrian president Bashar al-Assad, claimed credit for the Twitter and Huffington Post hacks in a series of Twitter messages. Electronic records showed that NYTimes.com, the only site with an hours-long outage, redirected visitors to a server controlled by the Syrian group before it went dark.
- Red October, 2012 – In October 2012, the Russian firm Kaspersky discovered a worldwide cyber-attack dubbed “Red October,” that had been operating since at least 2007. Hackers gathered information through vulnerabilities in Microsoft’s Word and Excel programs. The primary targets of the attack appear to have been countries in Eastern Europe, the former USSR and Central Asia, although Western Europe and North America reported victims as well. The virus collected information from government embassies, research firms, military installations, energy providers, nuclear and other critical infrastructures<sup>2</sup>.
- Canadian Government Attack – In January 2011, the Canadian government reported a major cyber-attack against its agencies, including Defense Research and Development Canada - a research agency for Canada's Department of National Defense. The attack forced the Finance Department and Treasury Board, Canada’s main economic agencies, to disconnect from the Internet<sup>3</sup>.

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<sup>1</sup>Infosec Institute – online at: <http://resources.infosecinstitute.com/the-ferizi-case-the-first-man-charged-with-cyber-terrorism/>

<sup>2</sup> The NATO Review – online at: <https://www.nato.int/docu/review/2013/Cyber/timeline/EN/index.htm>

<sup>3</sup> Ibid.

## **PROBABILITY/EXTENT**

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Terrorism is a threat everywhere, but there are some important considerations in evaluating terrorism hazards, such as the existence of facilities, landmarks, or other buildings of international, national, or regional importance. High-risk targets for acts of terrorism include military and civilian government facilities, international airports, large cities, and high-profile landmarks. Terrorists might also target large public gatherings, water and food supplies, utilities, and corporate centers. Furthermore, terrorists are capable of spreading fear by sending explosives or chemical and biological agents through the mail. Nonetheless, terrorism can take many forms and terrorists have a wide range of personal, political, or cultural agendas. Therefore, there is no location that is not a potential terrorist target.

The impacts of terrorism can vary in severity from nominal to catastrophic and are contingent upon the method of the attack, the volume of force applied, and the population density of the attack site. There may be significant, widespread loss of life as well as structural and economic losses.

The proliferation of digital systems and information, and electronic access to that information and those systems, puts cyber terrorism on the world stage. Hackers can access systems from anywhere in the world, with the potential to cause significant damage. Essentially any system connected to the internet or operating digitally is a potential target for cyber terrorists.

## **WARNING TIME**

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The initiation of an act of terrorism comes without warning. However, large scale coordinated attacks may require weeks or years of planning, which if detected by authorities, can provide warning of the impending attacks.

## **FUTURE CONDITIONS**

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### **Climate Considerations**

Changes to the climate do not have a direct impact on terrorism.

### **Changes in Development**

Many things need to be considered when evaluating future hazard conditions. Increases in population and/or population densities and the expansion of infrastructure may result in increased exposure and vulnerability, but growth and development aspects for terrorism hazards are not confined solely to the physical built environment and changes in population. Further globalization and advancements in technology must be evaluated in order to gain an understanding of the potential future conditions. Globalization is macro-level changes around the world, including movements of cultures, values, and people (Moghaddam, Heckenlaible, Blackman et al., 2016). In the short term, increasing the integration of culture, economics, technology, science, and social and political systems around the world can make information easily accessible, expand the technical knowhow of rogue organizations, and expand terrorism networks. Additionally, cultural appropriation and/or the expansion of western culture around the world can fuel terrorism by increasing animosity towards western societies. Globalization in the



21<sup>st</sup> century is driven by technological advancements that not only enable terrorist organizations with the ability to easily expand, communicate, and transfer resources around the world, but also may create new opportunities/ways terrorists can conduct attacks. Globalization, technological advancements, and society's increasing technological reliance may increase both the future probability and magnitude of terrorist attacks, but the future environment is widely uncertain.

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## **VULNERABILITY ASSESSMENT**

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Communities where potential targets are located should be considered more vulnerable. Larger cities like Phoenix, Mesa, Glendale and Tucson are the most vulnerable to terrorist attacks due to the sheer size of these urban areas, density of the population, multiple large sporting and entertainment venues, and concentrations of local, state, and federal critical infrastructure. Arizona has a sizeable tourism economy in regards to large sporting events, concerts, and conventions. Arizona has been known to host the NCAA Final Four tournament, the NFL Superbowl, large events like the Phoenix Comicon, the Ironman Triathlon, and various concerts. Terrorists have a documented history of targeting large gatherings of people in order to spread fear and inflict as much damage as possible. All events with large gatherings of people may be the most vulnerable to terrorist attacks. Additionally, because of its status as the state capital, Phoenix has an elevated vulnerability.

Of particular concern to Arizona are the many critical facilities in the state. Critical life-line infrastructure, such as bridges, tunnels, power and gas distribution facilities, and public water supply lines, may be potential terrorist targets. Damage to these facilities and infrastructure could cripple transportation routes and utilities, and their associated commerce. Additionally, there are many Title III facilities as well as transportation routes vital to the entire nation traversing Arizona, making intentional hazard material releases a potential threat to citizens and the environment.

Vulnerability to cyber-terrorism exists with any system connection to the internet or even internal non-connected operating systems. Vulnerabilities include informational databases, operational systems, communications networks, and more. Government and private entities are vulnerable alike.

One example of a worst-case scenario for a terrorism event in Arizona would be if a “dirty bomb” combining radioactive material with conventional explosives were to be detonated in Phoenix at lunchtime on a weekday. At that time of day and location, a significant number of individuals would be exposed to the bomb's radiation both at the time of detonation and after the fact as the radiation spread. The explosive device could damage or even topple buildings, spark utility outages citywide, and/or ignite large-scale urban fires. Prediction of terrorist attacks is almost impossible because terrorism is a result of human factors. As long as fringe groups maintain radically different ideas than that of the government or general population, terrorism is a possibility.

### **State Facility Loss Estimation**

All state facilities are vulnerable to terrorism in some way, with variable levels of risk. Since the probability of terrorism occurring cannot be quantified in the same way as many natural hazards, it is not possible to assess vulnerability in terms of likelihood of occurrence. Instead, vulnerability is assessed in terms of specific assets. FEMA's Integrating Manmade Hazards into

Mitigation Planning (2003) encourages site-specific assessments that are based on the relative importance of a particular site to the surrounding community or population, threats that are known to exist, and vulnerabilities including:

#### **Inherent Vulnerability**

- Visibility – How aware is the public of the existence of the facility?
- Utility – How valuable might the place be in meeting the objectives of a potential terrorist?
- Accessibility – How accessible is the place to the public?
- Asset mobility – is the asset's location fixed or mobile?
- Presence of hazardous materials – Are flammable, explosive, biological, chemical and/or radiological materials present on site? If so, are they well secured?
- Potential for collateral damage – What are the potential consequences for the surrounding area if the asset is attacked or damaged?
- Occupancy – What is the potential for mass casualties based on the maximum number of individuals on site at a given time?

#### **Tactical Vulnerability**

- Site Perimeter
  - Site Planning and Landscape Design – Is the facility designed with security in mind – both site-specific and with regard to adjacent land uses?
  - Parking Security – Are vehicle access and parking managed in a way that separates vehicles and structures?
- Building Envelope
  - Structural Engineering – Is the building's envelope designed to be blast-resistant? Does it provide collective protection against chemical, biological and radiological contaminants?
- Facility Interior
  - Architectural and Interior Space Planning – Does security screening cover all public and private areas?
  - Mechanical Engineering – Are utilities and HVAC systems protected and/or backed up with redundant systems?
  - Electrical Engineering – Are emergency power and telecommunications available? Are alarm systems operational? Is lightning sufficient?
  - Fire Protection Engineering – Are the building's water supply and fire suppression systems adequate, code-compliant and protected? Are on-site personnel trained appropriately? Are local first responders aware of the nature of the operations at the facility?
  - Electronic and Organized Security – Are systems and personnel in place to monitor and protect the facility?

#### **Vulnerable Population Groups**

The entire population is considered vulnerable to terrorist attacks, but certain population groups may be more vulnerable depending on the method used to carry out an attack. The entire population is dependent on technology and any cyber attack on the electrical grid would pose a threat to all. Additionally, children below the age of 18, especially below the age of five, the

elderly, the immunosuppressed, and those living in poverty may be more vulnerable to chemical, biological, and radiological attacks as they all have biological effects. Those living in poverty and the homeless may be more vulnerable to attacks based on the fact they may reside in high population density areas, and may have inadequate/insufficient housing to shelter in place. Additionally, police and military personnel may be specifically targeted by terrorist organizations.

### **Jurisdictional Losses**

Jurisdictional loss estimates can vary greatly in a terrorism event based on the magnitude and type of terrorist action. Catastrophic terrorism events will have proportionally catastrophic losses for the jurisdiction in question. For example, losses may be greater in an event that results in the complete destruction of a high-rise building; in that scenario, losses will stem from loss of life, the actual destruction of the building, and business interruptions. For comparison's sake, the total losses incurred by New York City in the September 11, 2001 attacks are estimated at \$83-95 billion. This loss estimate includes lost tax revenue for the city, the cost of response and recovery, business interruptions, deaths, building damage, and infrastructure damage. While Arizona's cities are smaller than New York, losses could still be severe.

## **POTENTIAL CONSEQUENCES AND IMPACTS**

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### **Public**

The effects of terrorism include, but are not limited to death, injury, illness, and a feeling of fear and helplessness in the general population. It can destroy property, lifelines, and the basic social fabric. On a large scale, it destroys major portions of a large city's infrastructure creating physical and economic hardship for some time in addition to the initial death and destruction. Long-term psychological damage to a portion of the population is also possible. Additionally, a terrorist event, especially cyber terrorism, can largely disrupt a community's way of life by preventing individuals from locating and communicating with loved ones, and preventing accessing money held in banks.

### **Property/Facilities/Infrastructure**

The type and magnitude of the terrorist attack will determine the damage or destruction to property, facilities, and infrastructure. Buildings can be destroyed or rendered unsafe, equipment, electronic or mechanical, ruined or in some cases made inaccessible due to damage or contamination. Files, electronic or paper, can be destroyed. Explosions and fire can render infrastructure such as roads, power lines, natural gas, fuel, water pipelines, and sewage control facilities inoperable.

### **Responders**

Impacts to responding personnel are similar to what can affect the citizens residing or working in the target area. They include medical problems and death from chemical agent exposure, explosion and fire trauma. There may long-term hazards such as hazardous chemicals or material (asbestos) that can cause illness, either acute or chronic.

### **Continuity of Operations/Delivery of Services**

The magnitude and type of event determine the impact on agencies and services. Continuity of operations for agencies that have their main administration or critical components of their operations within the target area could find their operational continuity at risk. If files, paper or electronic, are damaged or destroyed, an organization may not be able to: contact clients; assign work; complete scheduled jobs; meet deadlines; access, track, and pay accounts; or pay staff. Without a Continuity of Operations Plan that takes these issues into account, they may not be able to operate in their normal mode, if at all.

### **Environment/Cultural**

The impacts to the environment from a terrorist attack can be significant if not devastating. The infrastructure of a large city, if destroyed, can cause lingering problems with contaminants, pollutants, hazardous debris, etc. The effects of attacks on water supplies and food crops can linger for long periods of time rendering the land or water unusable. Radiological damage can close entire geographical areas for years. Damages to cultural sites and resources can be significant.

### **Economic/Financial Condition of Jurisdiction**

Economically, the after effects will depend directly on how much damage was done to local businesses, the local tax base, and the local infrastructure, and the type of terrorist activity. An individual home or business damaged by the attack can be devastating to an individual or family, it has very little effect on the overall economic condition of the community. However, when a large number of homes and businesses are damaged or destroyed, it can negatively alter the tax base decreasing the ability of the local jurisdiction to pay, not just for infrastructure repair and community restoration, but also for the normal day to day programs that make the community a viable area in which to live and work. People and business may need to relocate, and in some cases out of the community or state.

Damage to the business and industry sector does not only affect the tax base but may also remove jobs from the local economy. The loss of jobs can escalate into other problems. The unemployed may either move away, go on unemployment, or be forced to take a lower paying job, all of which further decreases the financial stability of the community. If the loss of financial stability is not corrected, there are other social problems that arise. Those out of work can develop a loss of self-esteem that can lead to an increase in crime, alcohol and drug abuse, psychological problems, spouse abuse, and an increase in medical problems

In summary, the economic viability of the area will depend on not just how much damage was done, but also on how quickly the infrastructure can be repaired; how prepared businesses are to operate in the post-disaster environment; how prepared citizens are for the possibility of an attack and its affects; and how well local governments and organizations can respond to the needs of the public for support, cleanup, and if necessary relocation.

### **Public Confidence in Jurisdiction's Governance**

The reputation of any individual jurisdiction within Arizona or the public's confidence in the jurisdiction is highly dependent on the public's perception of how well response and recovery are handled during and after an event. A response that either shows or gives the impression the jurisdiction is prepared and responsive to the public's needs and that it manages a recovery to



gets its services back and damage repaired in a timely manner will maintain or enhance a jurisdiction's reputation. However, if the perception develops, rightly or wrongly, that the jurisdiction is incompetent, slow to react, or ignores the needs of its citizens, the reputation of the jurisdiction and the confidence in its abilities may suffer. Additionally, identifying and apprehending the individual or group that carried out the terrorist attack will be vital to re-instilling a sense of safety and security in a community that just suffered from a terrorist event. Failure to do so may allow fear to persist in a community for an indefinite period of time.

### **Cascading/Secondary Impacts**

In addition to the impacts discussed above, acts of terrorism involving explosions or fire producing materials can lead to ignition of wildfires. Actions that cause the destruction of dams or levees could result in catastrophic flooding of downstream areas.

## **RESOURCES**

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AZ Counter Terrorism Information Center, <http://www.azactic.gov/>

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## WILDFIRE

A wildfire is an uncontrolled fire spreading through wildland vegetative fuels and/or urban interface areas where fuels may include structures. Wildfires often begin unnoticed, spread quickly, and are usually signaled by dense smoke that may fill the area for miles around. Wildfires can be human-caused through acts such as arson or campfires, or can be caused by natural events such as lightning. If not promptly controlled, wildfires may grow into an emergency or disaster, especially when burning in areas where people and infrastructure are located. Even small fires can threaten lives, resources, and properties.

## HISTORY

Wildfires burn thousands of acres in Arizona every year. According to the Southwest Coordination Center Historical Fire Data, during the 15-year period 2000-2015, Arizona had an annual average of 2,428 wildfires affecting an average of 264,035 acres each year. On average, 55% of the wildfires were human-caused, while 45% were lightning caused. The 2015 wildfire season overview found that 79% of fires in the Southwest burned in Arizona.<sup>1</sup>

Following are a few of the most significant wildfires in Arizona history:

- June 2015 - Whitetail Fire burned for 30 days covering 33,633 acres of Grassland and woodland in the central part of the San Carlos Apache Reservation. Fire management cost was \$2.8 million dollars and was the most significant fire monitored in the southwest for 2015 (Evans, 2016).
- June 2014 - San Juan Fire was a human-caused fire ignited on the Fort Apache Indian Reservation. The fire burned approximately 7,004 acres west of Springerville. The fire was declared controlled on July 8, 2014, with over \$5.8 million in fire suppression costs expended (Evans, 2014; AZCentral.com, 2014).
- May 2014 - Slide Fire began as a human-caused wildfire north of the Slide Rock State Park. The fire burned over 22,000 acres and had a firefighting cost of over \$7 million (NCDC, 2017).
- June-July 2013 - Yarnell Hill Fire, 8,400 acres. A lightning-caused fire that originated 3.5 miles west of the community of Yarnell. On Sunday, June 28th, the fire rapidly grew in size and intensity. Strong, erratic winds pushed the fire in several



<sup>1</sup> Evans, A., 2016, *2015 Wildfire Season: An Overview, Southwestern U.S.*, Ecological Restoration Institute and Southwest Fire Science Consortium, Northern Arizona University. 13 p.

directions at the same time. Nineteen members of the Granite Mountain Hotshot Crew lost their lives battling this fire on June 30, 2013. Residents of the communities of Yarnell and Peeples Valley were forced to evacuate. The Yarnell Hill Fire destroyed 108 homes in Yarnell and damaged an additional 25 others.

- June-July 2013 - Dean Peak Fire, approximately 5,400 acres. A lightning-caused fire in the Hualapai Mountains, 10 miles southeast of Kingman. This fire led to the communities of Pine Lake and Pinion Pine Estates being evacuated. No structures were lost.
- May-July 2011 - Wallow Fire, 538,049 acres. The human-caused Wallow Fire was ignited May 29, 2011 in an area west of Hannagan Meadow in the Apache National Forest. On June 8, 2011, the Governor declared an emergency as the 10-day-old fire continued to burn and spread out of control. When the fire grew to more than 200,000 acres, Eagar and Springerville were placed on pre-evacuation alert, and nearby Greer was evacuated. Shortly after that, the communities of Alpine and Nutrioso were evacuated as the fire moved easterly (Eastern AZ Courier, 2011). Finally, on July 8, 2011, the Wallow Fire was declared to be contained after burning a total of 538,049 acres (15,047 of which were located in New Mexico), becoming the largest fire in Arizona's history. Overall fire costs, in terms of damages and firefighting efforts, were estimated at over \$109 million with 16 firefighter related injuries reported. A total of 32 residences, four commercial properties, 36 outbuildings, and one vehicle were destroyed. Many more millions of dollars are estimated to have been spent on BAER Team recovery and post fire flooding mitigation efforts (InciWeb, 2011; AZ Family News, 2011, Apache County, 2017).
- June 2005 - Cave Creek Complex, 248,310 acres. Arizona's third largest wildfire in state history was caused by lightning from a summer thunderstorm. This desert fire burned thousands of acres within the first hour and threatened several communities on the outskirts of metropolitan Phoenix. The fire destroyed 11 homes in the Camp Creek community, with losses estimated at \$1.5 million. The fire eventually claimed one of Arizona's largest saguaros, the 46-foot Grand One near Horseshoe Lake.
- June 2003 - Aspen Fire, 84,750 acres. The Aspen fire burned for nearly a month on the slopes of the Santa Catalina Mountains and destroyed 340 homes and business in the community of Summerhaven. Total property damage was estimated at \$66 million, with \$16 million in suppression costs and \$33 million in lost timber revenue.
- June 2002 - Rodeo/ Chediski, 468,638 acres. This fire caused 30,000 people to evacuate, destroyed over 450 homes, and caused an estimated \$122.5 million in direct damages. The second largest fire in Arizona history started when an arsonist set the Rodeo Fire on the Fort Apache Indian Reservation near the Rodeo Fairgrounds. On June 20, a second blaze began near Chediski Peak, 15 miles from the Rodeo fire. The two fires spread quickly northeast and steadily widened toward each other, combining on June 23. On



Wallow Fire burning near in Lee Valley area near Big Lake, AZ  
Source: Kevork Djansezian - Getty Images

June 25, President Bush declared a national disaster for Apache, Coconino, Gila, Navajo Counties, and the Fort Apache Reservation. An estimated \$46.5 million was spent fighting the fire. Over 58% of the burned area experienced a high-intensity burn, and extensive smoke damage occurred in Apache County outside the direct burn area (FEMA and USFS, September 2002).

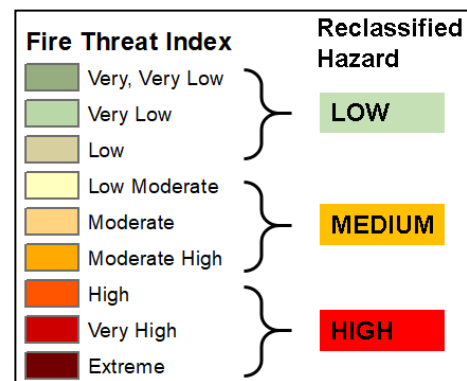
## PROBABILITY/EXTENT

Based on history, the probability of wildfire occurring in the state is very high. The magnitude and severity of wildfire incidents can be very high and are influenced by numerous factors including vegetation densities, previous burn history, hydrologic conditions, climatic conditions such as temperature, humidity, and wind, ignition source (human or natural), topographic aspect and slope, and remoteness of area. The primary dataset used to depict the threat of wildfire in Arizona was recently developed as a part of the West Wide Wildfire Risk Assessment<sup>1</sup> (WWWRA) for the western US, and hosted by the Arizona Department of Forestry and Fire Management on its website<sup>2</sup>.

The wildfire hazard areas used in this update are derived from the Fire Threat Index (FTI) data distributed with the WWWRA. The FTI reflects the likelihood of one acre burning if a fire started at a specific grid location. The calculation process integrates the probability of an acre igniting and the expected final fire size into a single measure of wildland fire susceptibility. The assessed fire size is based on the rate of spread in four weather percentile categories.

The key inputs used in the wildfire model to produce the FTI wildfire hazard layer are:

- Probability of fire occurrence, derived from:
  - Historic fire locations and fire occurrence areas
  - Weather influence zones (historic weather observations)
- Fire behavior (rate of spread) derived from:
  - Surface fuels
  - Canopy closure
  - Canopy characteristics
  - Topography
- Fire suppression effectiveness, derived from:
  - Historic fire sizes
  - Historic protection organization



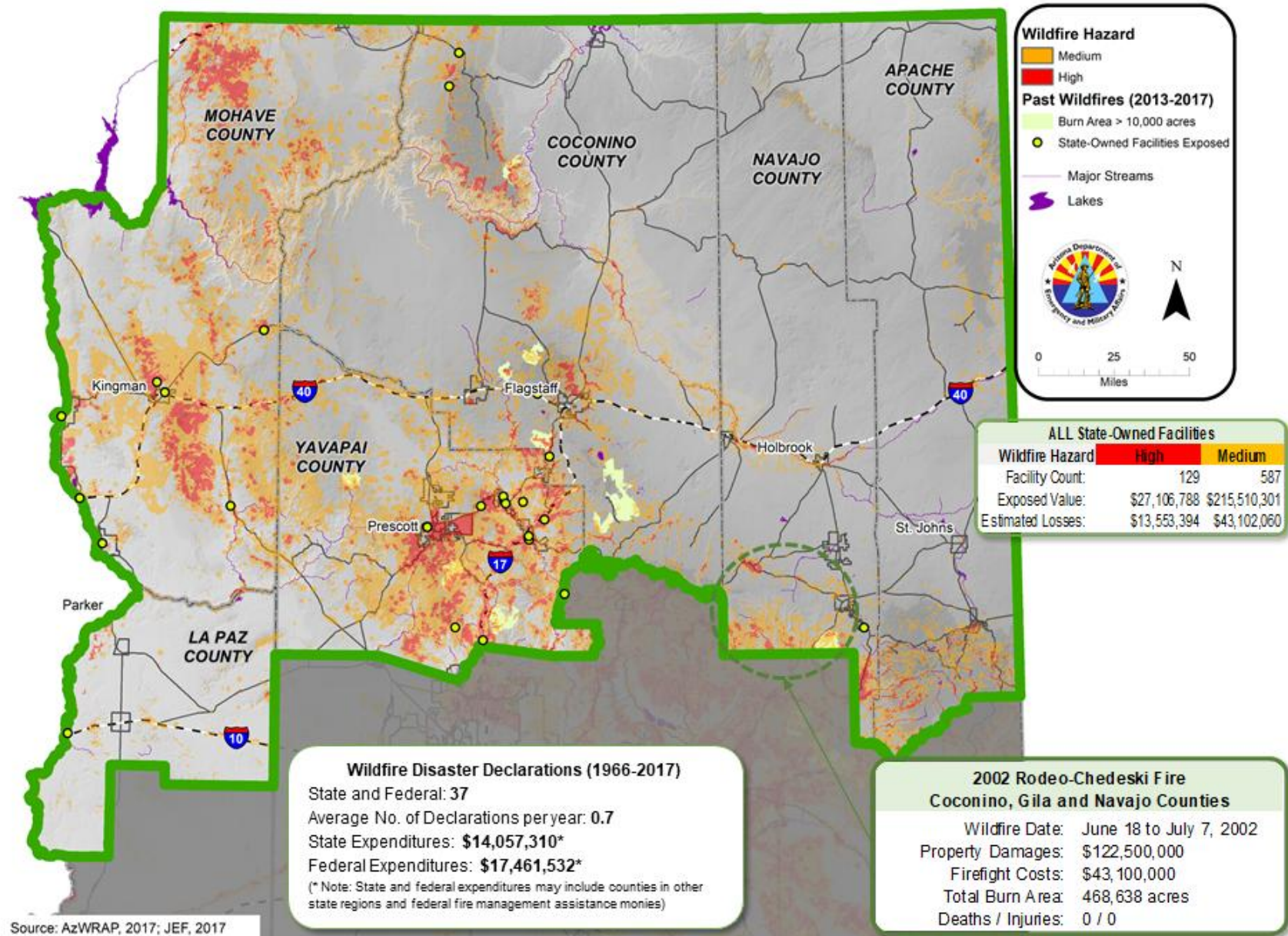
**Figure 11: Fire Threat Index**

For the purposes of this Plan, the nine FTI categories were reclassified into three generalized categories, Low, Medium and High wildfire hazard.

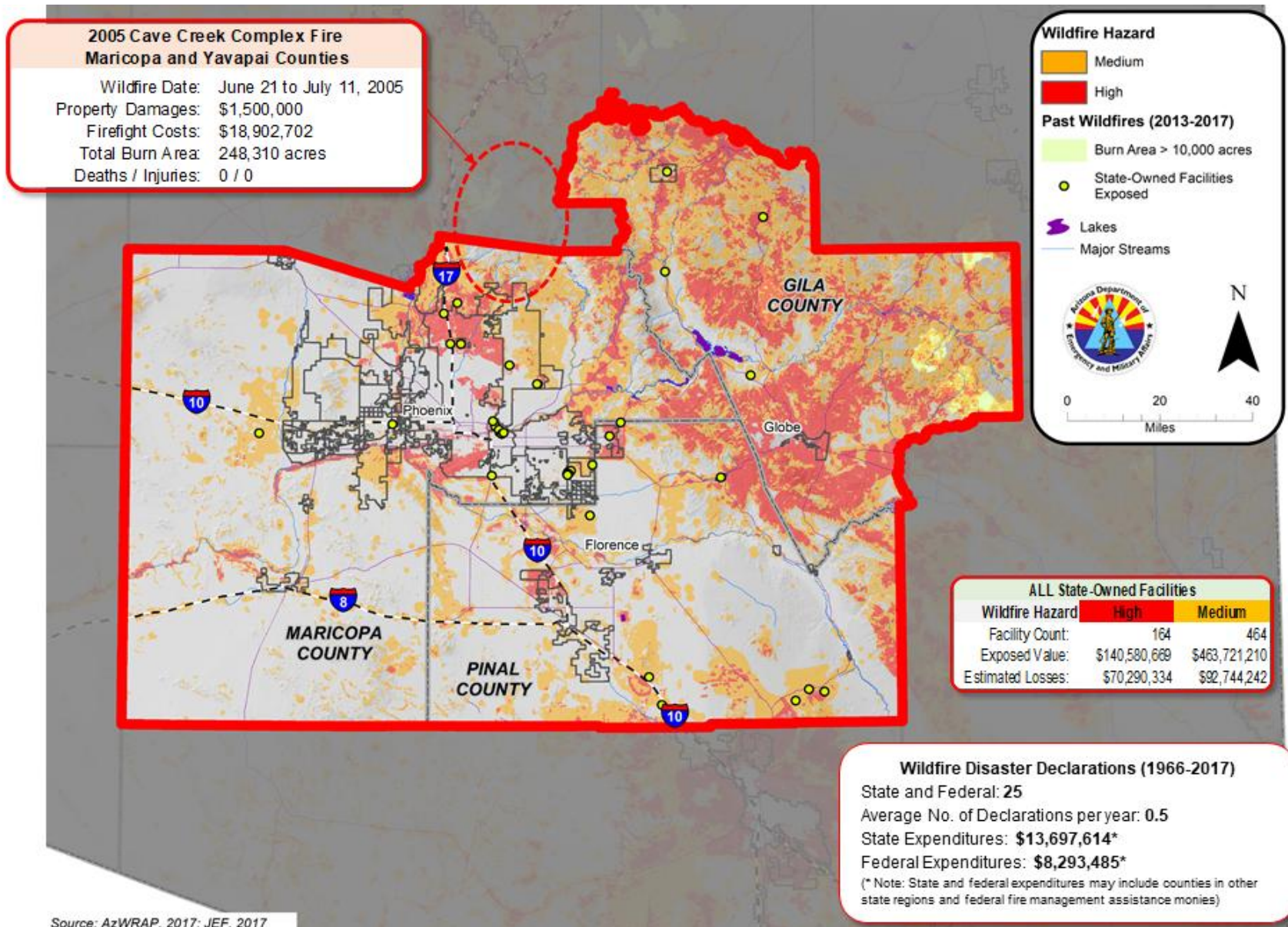
<sup>1</sup> Sanborn Map Company, 2013, *West Wide Wildfire Risk Assessment, Final Report*, prepared for the Oregon Department of Forestry in cooperation with the Western Forestry Leadership Coalition and Council of Western State Foresters.

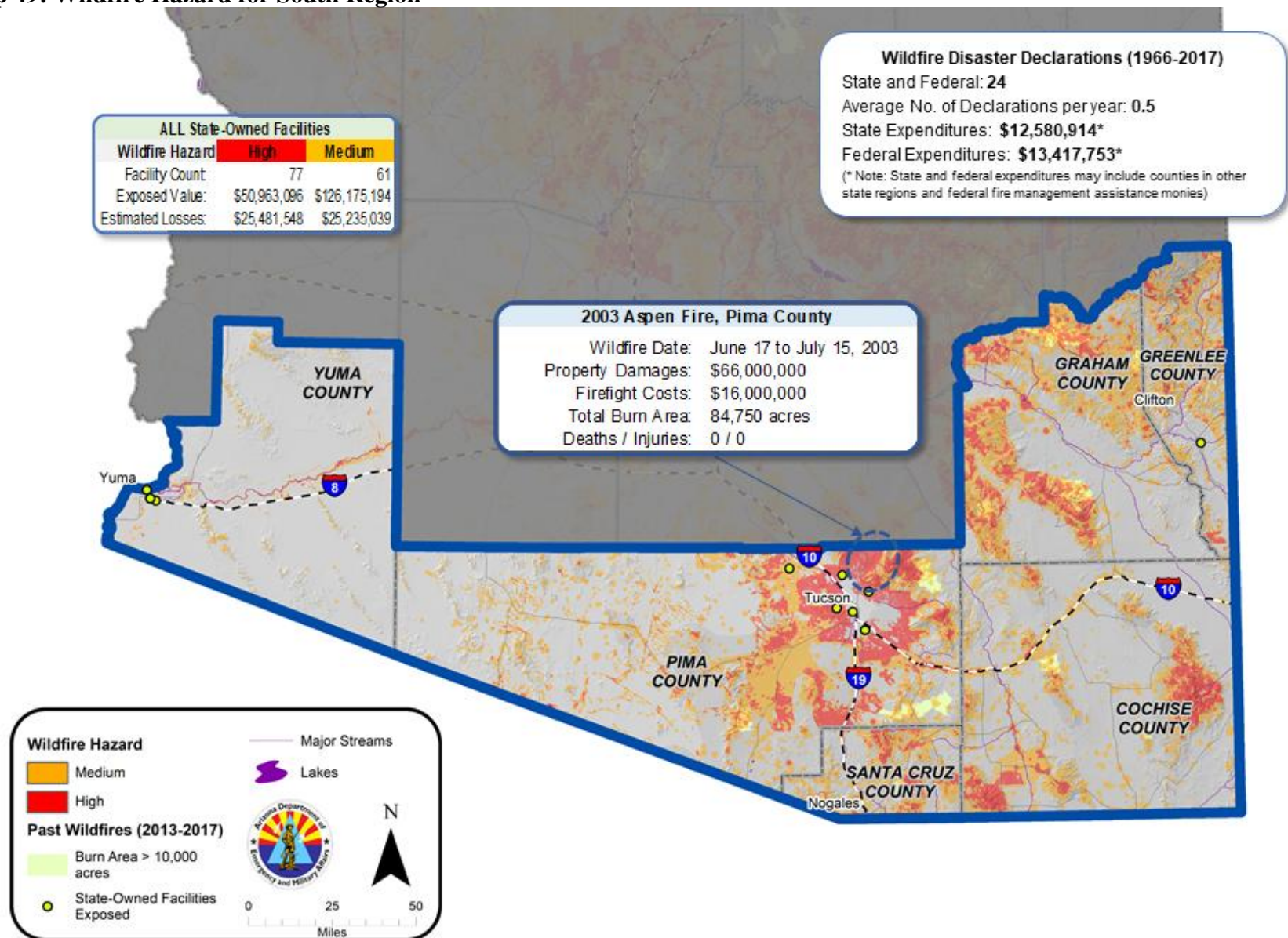
<sup>2</sup> Arizona Wildfire Risk Assessment Portal (AZWRAP), accessed at: <https://arizonawildfirerisk.com/>



**Map 47: Wildfire Hazard for North Region**



**Map 48: Wildfire Hazard for Central Region**

**Map 49: Wildfire Hazard for South Region**

Source: AzWRAP, 2017; JEF, 2017



## WARNING TIME

Warning time for wildfire incidents is multi-faceted. There is little to no warning time for the ignition of most fires. Once a fire has started and has been detected, a second level of warning comes in the form of the potential need for evacuations, which can be in hours or days, depending on the fire's location and proximity to populated areas. The state can monitor the size and growth of the fire in real time, which optimizes the ability to give responders time to evacuate at-risk homes and residents.

## FUTURE CONDITIONS

### Climate Considerations

The NCA report (Garfin, et.al., 2014) notes that one of the anticipated impacts of climate change for the Southwest is an increase in the frequency and magnitude of wildfires due to increased temperatures and seasonal reductions in snowpack and spring runoff. The NCA report also notes that drought conditions are expected to be more frequent and more intense. The Ecological Restoration Institute's (ERI) Working Paper No. 34 (Kent, 2015) concludes:

*"Climate change may impact fire through three pathways: alteration of fuel moisture, alteration of fuel loading, and alteration of ignitions. Alteration of fuel moisture in the Southwest may happen through longer fire seasons, increased temperatures, decreased relative humidity, or changes in precipitation. Alteration of fuel loading has been predicted due to tree mortality and loss of vegetation cover, range shifts, changes in regeneration patterns, and disturbances themselves, such as insect outbreaks and severe fire. Lightning ignitions may increase, but ignitions are the least understood aspect of how climate change may influence fire.*

*Different ecosystems will respond to climate change differently. Ecosystems in which fires are generally limited by fuel moisture (wetter, more productive ecosystems which typically need a drought year to burn) will be most affected by changes to fuel moisture. Ecosystems in which fires tend to be limited by fuel availability (drier, less productive ecosystems in which fire may be limited by fuel continuity) will be most affected by changes to fuel loading. Any changes in ignitions will likely affect all ecosystem types. The impacts of climate change on fire regimes may change over time; fire risk may be high initially but decrease in the long term with changes in vegetation and fuels."*

### Changes in Development

Expansion of the wildland urban interface (WUI) due to development and population growth may increase the risk and exposure of structures and people to wildfire.

#### North Region

Apache, La Paz, and Navajo Counties have experienced little to no growth over the past five years, nor is there any major growth or development of the WUI anticipated over the next five years. Moderate in-fill growth has occurred in Coconino, Mohave, and Yavapai Counties and the trends of the past five years are anticipated to continue with most of the growth being centered around existing population centers and limited in the WUI. Areas



of anticipated significant growth that may extend into the WUI boundaries are identified in the Flagstaff and Tusayan (Coconino), Prescott Valley and Chino Valley (Yavapai), Kingman, Bullhead City and Lake Havasu City (Mohave), plus several populated areas within the unincorporated areas of Coconino, Mohave, and Yavapai Counties.

### Central Region

Moderate growth has occurred in Maricopa and Pinal Counties over the past five years, and primarily in the build-out of previously planned residential, industrial and commercial areas. Some of that growth has occurred in the WUI. Growth in Gila County has been mostly limited to the Payson area and mostly in-fill. Planned growth in WUI areas is anticipated to be heaviest in Maricopa County and lesser in Pinal and Gila Counties.

### South Region

Pima and Yuma Counties have experienced moderate growth over the past five years in some locations and population declines in others. Cochise County experienced moderate growth within Douglas and Sierra Vista, but generally a decline in the overall population. Graham County saw limited growth that is mostly attributable to the development of the new Freeport McMoRan mining operations. Santa Cruz and Greenlee Counties have experienced limited to no significant growth. Region-wide, most of the growth has been in-fill related with limited expansion of the WUI. Planned growth in WUI areas over the next five years is anticipated to be limited in Pima and Yuma Counties and insignificant in Cochise, Graham, Greenlee, and Santa Cruz Counties.

## VULNERABILITY ASSESSMENT

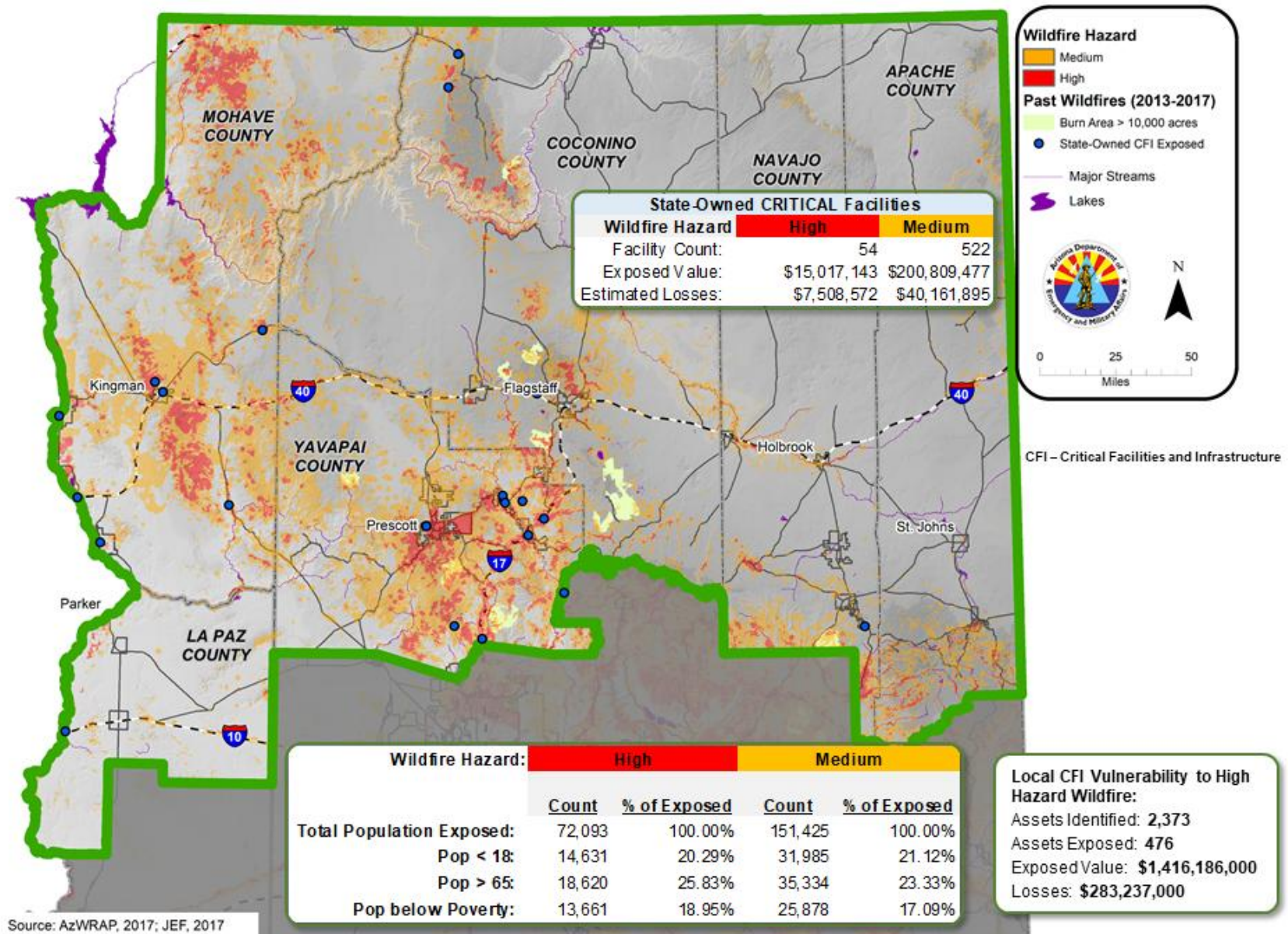
The estimation of potential exposure to the identified high and medium wildfire hazards was accomplished by using GIS tools to intersect the human and state-owned critical facilities and infrastructure (CFI) data with the wildfire hazard limits depicted on the profile maps. The loss calculations assume that facilities located within high and medium hazard areas will be 50% and 20% damaged, respectively. The loss estimates presented are based on a single event and assume that the entire region is burning to the depicted hazard at the same time.

### North Region

The North Region has the greatest vulnerability to wildfire hazards when considering the available fuels, the number of historic declarations, and the number of people and structures located within the WUI.

#### State-Owned CFI Exposure and Loss Estimates

A total of 54 state-owned CFI, or 25.0% of the statewide exposure, are located within a high hazard area. The exposed facilities represent a total exposed replacement value of \$15.0 million, with an estimated \$7.5 million in potential losses. For the medium hazard, a total of 522 state-owned CFI, or 72.6% of the statewide exposure, are exposed and represent a total replacement value of \$200.8 million, with an estimated \$40.2 million in potential losses.

**Map 50: Wildfire Vulnerability for North Region**

### Vulnerable Population Groups

The 2015 estimated total population for the North Region is 772,157 people. Approximately 9.34% and 19.61% of the total population, or 72,093 and 151,425 persons, are exposed to high and medium wildfire hazards. Each of the vulnerable population groups analyzed were approximately 8 to 12% of the total population exposure to high wildfire hazard and roughly 15 to 23% of the total population exposure to medium wildfire hazard. Approximately 7.3% of the North Region population is estimated to have a Limited English Proficiency (LEP) (US Census Bureau, 2016). Assuming the percentage is equally applied across the whole region's population, roughly 5,263 and 11,054 LEP persons (7.3% of 72,093 and 151,425) are estimated to be exposed to high and medium wildfire hazard.

### Local Jurisdiction Vulnerability

Local hazard mitigation plans for the North Region identified a total of 476 assets with a total replacement value of \$1.42 billion. Total potential losses to local CFI were estimated at \$283 million.

### Specific Areas of Concern

The North Region has large swaths of publicly accessible lands that serve as recreation areas for a wide population of the state. Those same areas are exposed to human-caused wildfire ignition potential through campfires, cooking equipment, and vehicles. In Mohave County, the northern Hualapai Mountains have substantial high hazard areas with limited road access and several small communities. There are also significant areas of high hazard surrounding Flagstaff, Williams, Prescott, and Sedona, which all have a large population of residents and structures located within the WUI.

## Central Region

Among the three state regions, the Central Region is considered equally vulnerable to wildfires as the South Region and less vulnerable than the North. The Central Region also has the largest WUI population; however, most of the wildfire hazards in those areas are low to medium, with some high hazard areas located along the northern boundary of the Phoenix Metropolitan area.

### State-Owned CFI Exposure and Loss Estimates

A total of 123 state-owned CFI, or 56.9% of the statewide exposure, are located within a high hazard area. The exposed facilities represent a total exposed replacement value of \$130.7 million, with an estimated \$65.4 million in potential losses. For the medium hazard, a total of 136 state-owned CFI, or 18.9% of the statewide exposure, are exposed and represent a total replacement value of \$26.7 million, with an estimated \$5.3 million in potential losses.

### Vulnerable Population Groups

The 2015 estimated total population for the Central Region is 4,604,414 people. Approximately 3.97% and 5.24% of the total population, or 182,710 and 241,348 persons, are exposed to high and medium wildfire hazards. Each of the vulnerable population groups analyzed were at approximately 2-5% of the total population exposure

to high wildfire hazard and roughly 3-7% of the total population exposure to medium wildfire hazard.

On average, approximately 6.7% of the Central Region population is estimated to have a Limited English Proficiency (LEP) (US Census Bureau, 2016). Assuming the percentage is equally applied across the whole region's population, roughly 12,242 and 16,170 LEP persons (6.7% of 182,710 and 241,348) are estimated to be exposed to high and medium wildfire hazard.

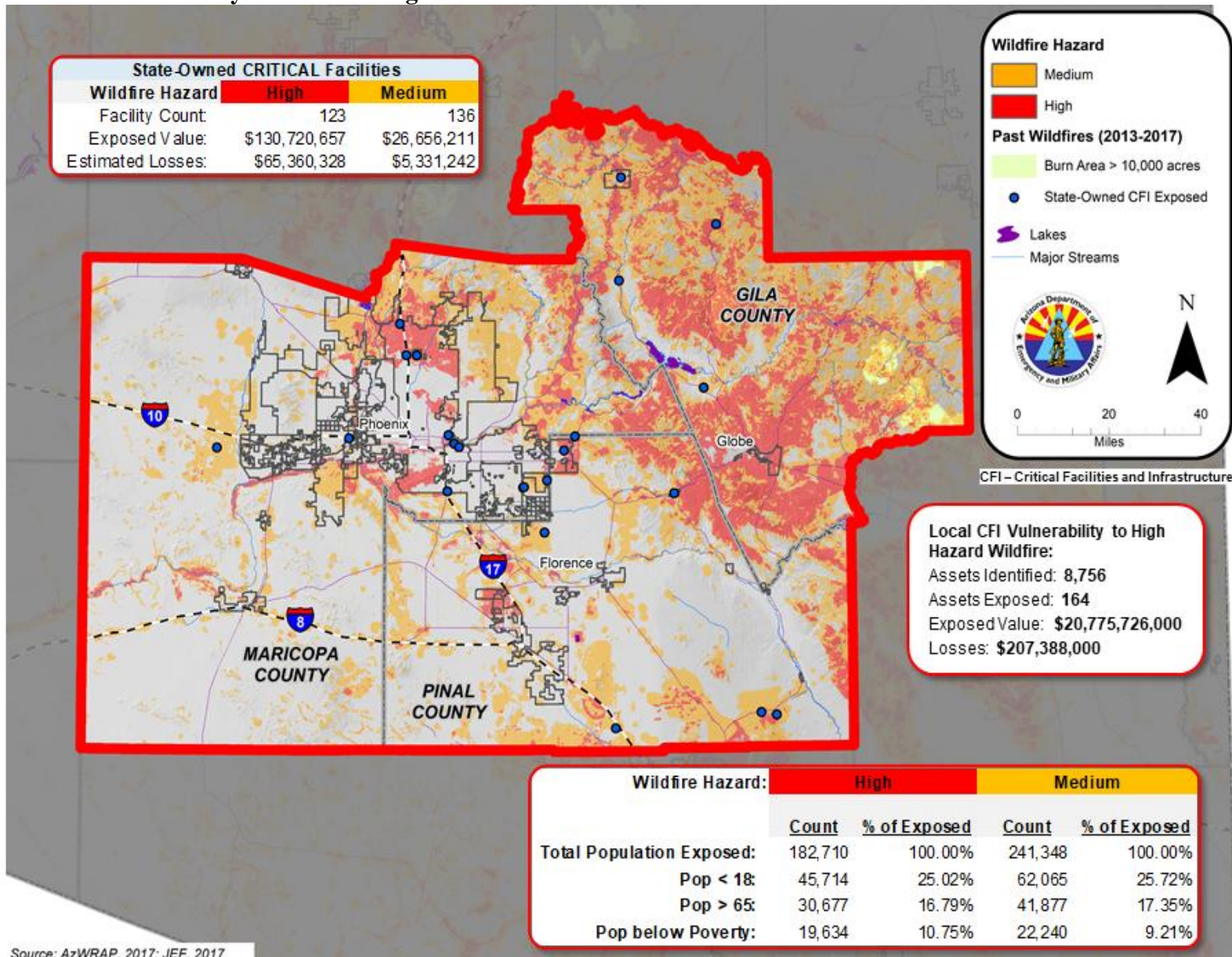
### Local Jurisdiction Vulnerability

Local hazard mitigation plans for the Central Region identified a total of 164 assets with a total replacement value of \$20.8 billion. Total potential losses to local CFI were estimated at \$207.4 million.

### Specific Areas of Concern

Most of the Central Region has less fuel loading as compared to the North Region. However, there remain significant areas along the WUI perimeter that are vulnerable to wildfire. The exception to this are the northern higher elevation areas of Gila County (Payson, Globe, Strawberry, and Pine), which have significant fuels and intermixed people and structures. Many of the river beds and regional watercourses have dense stands of overgrown salt cedar, which when ignited, can burn very hot and threaten nearby structures.



**Map 51: Wildfire Vulnerability for Central Region**

## **South Region**

Among the three state regions, the South Region is considered equally vulnerable with the Central Region and less vulnerable than the North.

### **State-Owned CFI Exposure and Loss Estimates**

A total of 39 state-owned CFI, or 18.1% of the statewide exposure, are located within a high hazard area. The exposed facilities represent a total exposed replacement value of \$38.3 million, with an estimated \$19.2 million in potential losses. For the medium hazard, a total of 61 state-owned CFI, or 8.5% of the statewide exposure, are exposed and represent a total replacement value of \$126.2 million, with an estimated \$25.2 million in potential losses.

### **Vulnerable Population Groups**

The 2015 estimated total population for the South Region is 1,458,367 people. Approximately 14.55% and 7.28% of the total population, or 212,219 and 106,146 persons, are exposed to high and medium wildfire hazards. Each of the vulnerable population groups analyzed were at approximately 8-18% of the total population exposure to high wildfire hazard and roughly 5-8% of the total population exposure to medium wildfire hazard.

On average, approximately 12.7% of the South Region population is estimated to have a Limited English Proficiency (LEP) (US Census Bureau, 2016). Assuming the percentage is equally applied across the whole region's population, roughly 26,952 and 13,480 LEP persons (12.7% of 212,219 and 106,146) are estimated to be exposed to high and medium wildfire hazard.

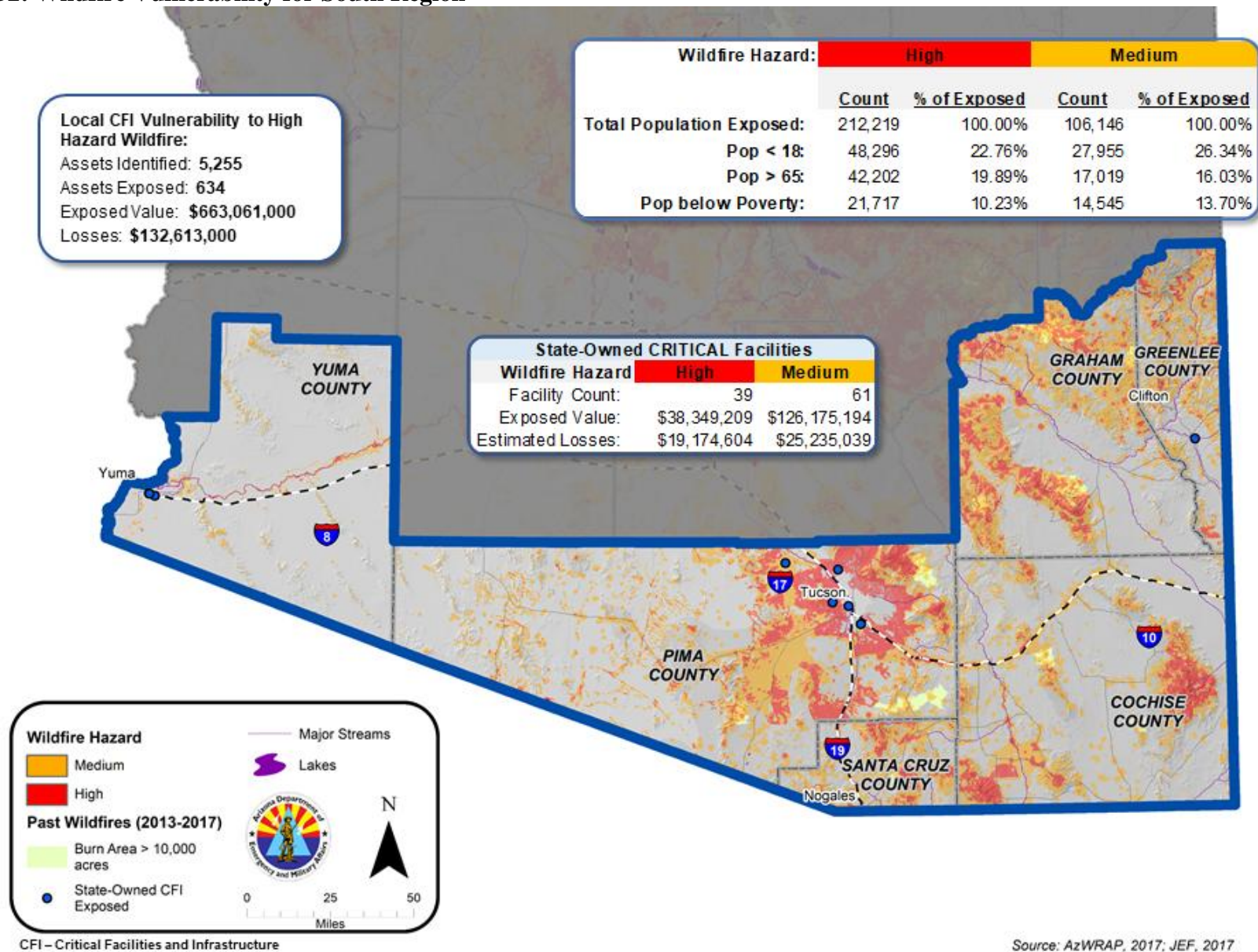
### **Local Jurisdiction Vulnerability**

Local hazard mitigation plans for the South Region identified a total of 284 assets with a total replacement value of \$663 million. Total potential losses to local CFI were estimated at \$132.6 million.

### **Specific Areas of Concern**

The foothills surrounding the Tucson Metropolitan area are predominantly indicated to have a high wildfire hazard, with a significant number of people and structures exposed. The mountainous areas on the eastern and northern portions of the region have a higher wildfire potential, but limited population and structure exposure. As with the Central Region, many of the river beds and regional watercourses have dense areas of overgrown salt cedar, which when ignited, can burn very hot and threaten nearby structures.



**Map 52: Wildfire Vulnerability for South Region**

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## POTENTIAL CONSEQUENCES AND IMPACTS

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### Public

The impact to the general public from wildfire is typically injuries (burns), illness (smoke inhalation & psychological), and even death. This risk extends to property owners, users of recreational areas vulnerable to fires, and motorists near these areas. During fires that threaten populated areas, evacuation plans are exercised. Over the years, Arizona has evacuated thousands of residences, providing shelter for the citizens as well as pets and livestock.

There may be secondary risks to the public from air quality impacts from fires, and from increased risk of flash flooding downstream of burned areas. All regions have exposure to flash flooding caused by wildfires in upstream watersheds. This increased risk of flash flooding continues for years after the fire as the burned watershed slowly recovers. Fire may also negatively affect water quality and downstream water users.

### Property/Facilities/Infrastructure

Structures, facilities, and above ground infrastructure can be significantly damaged or destroyed by wildfire. Wooden power poles and cross-members can be burned and the heat from a fire can warp metal. Smoke from a wildfire can cause high voltage transmission lines to arc across the wires with the potential for severing the wire itself. Cable coatings can also be melted.

### Responders to the Incident

Responders are at significant risk from wildfires. Responders are involved in firefighting activities, evacuation, public health services for evacuation centers, and law enforcement activities, with firefighting posing the most hazardous activity. Multiple deaths have occurred in past Arizona firefighting, including six killed during the Dude Fire and 19 killed fighting the Yarnell Fire. Firefight related injuries are also common. Other threats to responders may include exhaustion and dehydration resulting from prolonged firefighting in very large fires that continue for extended periods of time. Long-term effects of exposure to fire retardants and chemical releases, as well as explosions due to burning fuel tanks or vehicles are also possible.

### Continuity of Operations/Delivery of Services

As is discussed in other hazard sections of this Plan, the level of effectiveness of a specific facility/service would be dependent on the severity of the hazard and how much damage the facility and its equipment and files, etc. sustain. Even with certain critical facilities remaining operational, the performance and delivery of services may easily be hindered during an event due to damaged, closed and impassable roads. In the case of a wildfire, travel may be affected by damaged transportation routes, no traffic control resulting from power outages, and blocked routes due to downed trees and/or power poles. Smaller jurisdictions with little or no wildfire experience may have limited staff and resources which may inhibit their ability to continue operations/services. Arizona has several small, somewhat isolated communities in wildfire-prone areas. These jurisdictions are less likely to have the ability to remain operational and self-sustaining during and after an event. Larger jurisdictions typically have more facilities, infrastructure, equipment and staff and are usually more spread out over multiple areas. This



leaves these operations less vulnerable, especially when they can operate out of a variety of locations.

### **Environment/Cultural**

Wildfires create long-term impacts on the environment. The loss of ground cover may increase the risk of erosion, debris flows, and flooding. Forest and rangelands take years to recover from the effects of a wildfire, and during this time, the public loses many of the benefits. Wildlife can also lose valuable habitat. Wildfires enhance the propagation of invasive species such as tamarisk (salt-cedar) and buffel grass, making their control more difficult and expanding their coverage. Smoke from a wildfire can impact communities hundreds of miles downwind. Ash and debris transported by post-fire flooding can suffocate and kill aquatic life in streams and lakes. Erosion and loss of topsoil in high intensity burn areas can leave hillsides barren for decades.

Cultural impacts to a community can be long-lasting as the character of the landscape is scarred for years following a wildfire. Destruction of sacred structures, archeological sites, houses of worship, and historic landmarks and structures can completely change the cultural setting and atmosphere of the impacted communities.

### **Economic/Financial Condition of Jurisdiction**

Economic impacts to an area start with the ignition of a fire and will continue long after the fire has been suppressed. Financial losses caused by the evacuation of at-risk areas can disrupt local business, tourism, and industrial activities. Damage and destruction to personal property and structures is often un-insured and creates extreme hardship for the impacted individuals and families. Losses of public facilities and infrastructure damages are also possible. Lumber industries can be significantly impacted if timber stands are severely burned and rendered unusable. Local jurisdictional resources can be stretched thin when addressing relocation needs for displaced individuals and rebuilding destroyed infrastructure. Alternately, infusions of disaster funding and provisions for short-term food and housing can create a small spike in a local community's business and sales.

### **Public Confidence in Jurisdiction's Governance**

The effects of wildfire are destructive and disruptive to jurisdictions and often continue after the fire has been suppressed. Power outages are likely, and travel may be hindered or completely stopped for a period of time. Some government functions may be reduced or lost. Public employees may be removed from normal duties to help in the response and recovery efforts, putting less critical government operations on hold. Impacted public facilities may require relocation or suspension of services. The cumulative effect of all or part of these issues may leave the public discouraged.

### **Cascading/Secondary Impacts**

The indirect effects of wildfires can be catastrophic. Smoke from wildfires often has severe impacts on the health of both firefighters and residents. Wildfires affect critical public infrastructure, business and the economy, local government budgets, and have many other significant cascading effects. In addition to stripping the land of vegetation and destroying forest resources, large, intense fires can harm the soil, waterways, and the land itself. Soil exposed to extreme heat may lose its capability to absorb moisture and support life. Exposed soils erode quickly and enhance siltation of rivers and streams thereby increasing flood potential, harming

aquatic life, and degrading water quality. Lands stripped of vegetation are also subject to increased landslide hazards.

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## WINTER STORM

Winter storms in Arizona can include heavy snowfall, freezing rain, and sleet. Heavy precipitation associated with winter storms has the potential to collapse roofs, topple trees and power poles, and cause road closures due to rapid accumulation of snow or ice. Winter highway conditions can turn injurious or even deadly, with slippery or icy roads causing multi-vehicle accidents, hypothermic exposure to cold and wet conditions, and impassable roads stranding travelers, isolating residents, and preventing emergency response.



ADOT snow plow clearing snow on SR260 east of Payson, AZ  
Source: (azfamily.com, 2011)

## HISTORY

Arizona has had a total of six state declarations related to winter storm events that included some blending of higher altitude snow accumulation and lower altitude rainfall and flooding. Two of those events received a presidential disaster declaration. Since 2013, at least 34 winter storms were identified for Arizona, with a reported \$640,000 in damages and no reported injuries or deaths (NCEI Storm Event Database).

The following represent some of the more significant winter storms in Arizona's history:

- January 20-21, 2017 - A winter storm caused heavy snow and damaging winds on the Santa Catalina, Chiricahua, Galiuro, Pinaleno, Dragoon, and Rincon Mountains. Power was lost to Mount Lemmon for 48 hours and communication towers were inoperable for several hours. Roads were blocked from snow and rain triggered rock slides that also damaged guard rails. Storm-wide damages were estimated to exceed \$177,000 (NCEI, 2017).
- January 18-23, 2010 - A series of strong Pacific winter storms produced lower altitude rain and heavy mountain snow to fall over a significant portion the north half of the state. Heavy snow closed roadways and caused numerous traffic problems and stranded vehicles. Strong winds accompanying the storms also created blizzard conditions for several hours. DPS responded to over 150 requests for help, 14 non-injury collisions, and four injury



Roof damage from January 2010 snow storm in Flagstaff, AZ  
Source: Betsy Bruner, AZ Daily Sun



collisions. There was one fatal crash about six miles east of Flagstaff. In Flagstaff, 10-15 buildings either suffered from collapsed roofs or developed structural problems because of the weight of over 25 inches of snow that fell during the week of storms. The City of Flagstaff issued an emergency order requiring all buildings with flat roofs to be cleared of snow and ice<sup>1</sup> On February 16, 2010, the Governor requested a major disaster declaration due to a severe winter storm/snowstorm emergency during the period of January 18-22, 2010, and then amended the request on February 24, 2010, to include flooding and high winds and to clarify that the request was for a severe winter storm, snowstorm, flooding, and high wind event. A presidential disaster declaration was received on March 18, 2010.

- November 28, 2009 - The early stages of an approaching winter storm caused a bridge to ice up on I-17 near Munds Park. A semi-truck slid on the ice, crossed a median and struck an officer investigating a van rollover. The officer was pinned under a third vehicle; other drivers were able to lift the vehicle off the officer, free him, and call for help. He was taken to a local hospital where he was in critical but stable condition. Property damages were estimated to exceed \$100,000 (NCEI Storm Event Database).
- October 28, 2009 - A departing low-pressure center brought snow showers and cold conditions to the Flagstaff area during the afternoon and early evening which lead to icy roads and a few dozen car wrecks. The Department of Public Safety reported 11 collisions, Coconino Co Sheriff's Office reported seven traffic accidents with injuries, and the Flagstaff Police Dept. reported 14 traffic accidents. A parked DPS patrol car was hit and totaled by a truck that slid on the ice on I-40 just west of Flagstaff. The officer was out of his vehicle investigating a single vehicle roll over and was not hurt. Property damages were estimated to exceed \$400,000 (NCEI Storm Event Database).
- December 2008 - A three-day winter storm in northern Arizona dropped 24 inches of snow at 7,000 ft, and nearly 48 inches at 9,000 ft. resulting in hazardous road conditions with the Department of Public Safety reported 188 cars slid off the highway in northern Arizona, and 65 collisions, 12 with injuries (NCEI Storm Event Database).
- March 2008 - An intense winter snow storm reduced visibility to zero on I-40 near Flagstaff, leading to a 139-vehicle pile-up covering four miles on both sides of the highway. Eastbound lanes were closed for 14 hours, westbound for 16 hours. Two deaths were reported, along with 10 people hospitalized with serious injuries and another 35 people treated and released (NCEI Storm Event Database).
- January 2005 - A powerful winter storm moved across northern Arizona beginning January 3rd and ending January 5th. Widespread snowfall was reported with depths ranging between four and 45 inches depending on elevation. Heavy rainfall also occurred in lower elevation areas generally south of the Mogollon Rim. Approximately 800 homes were without power in Walker (southeast of Prescott) when wet heavy snow broke the community's main power line. Two teenagers were killed on January 3rd when their car slid on ice and hit a truck south of Hon Dah in the White Mountains. Impacts from this storm, combined with late December 2004 and early January 2005 flooding, prompted a

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<sup>1</sup> AZCentral.com article at: <http://archive.azcentral.com/arizonarepublic/news/articles/2010/01/23/20100123arizona-weather-storm0123.html#ixzz54IRI4Zsh>

gubernatorial declaration that then led to a presidential disaster declaration on February 17, 2005 (NCEI Storm Event Database and FEMA).

- November 2001 - The first storm of the season with measurable snow caused dozens of rush-hour traffic accidents along the Mogollon Rim, resulting in one fatality and five injuries. Most of the accidents occurred on Flagstaff city streets as the roads became snow packed and icy. City police handled more than 40 accident calls. County officials reported less than 10 accidents. Jack-knifed semis caused eastbound traffic on I-40 to come to a standstill, five miles east of Williams. There was a fatal crash on I-40 three miles east of Seligman (NCEI Storm Event Database).
- January 1997 - Perhaps the largest snow storm of the decade brought paralyzing heavy snow to most of northern Arizona, beginning in the early morning of the 12<sup>th</sup> and lasting through the night of the 14<sup>th</sup>. Four Navajo Nation deaths from exposure occurred during, or immediately after the storm, and multiple post-storm evacuations and livestock emergency food drops were performed by the National Guard. Numerous trees fell on cars, houses and roads causing power outages and property damage. Hundreds of miles of major highways were closed mainly along the Mogollon Rim and the White Mountains area. Highways surrounding Flagstaff were the most affected with closures of I-40 from Winslow to Ashfork and I-17 from Cordes Junction to Flagstaff. Over 200 vehicles were stranded on these two highways. The heavy snow in Flagstaff caused Northern Arizona University to close for the first time in 20 years. The Governor declared a State of Emergency for Coconino, Gila, and Navajo counties on January 14, 1997 (NCEI Storm Event Database).
- December 1967 to January 1968 - Two back-to-back storms combined to be one of the worst winter storms to impact Arizona, paralyzing most of the northern region and bringing snow, rain and flooding to much of the state. During the nine-day period, a record 86 inches of snow fell at Flagstaff. On December 14<sup>th</sup>, a one-day station record of 32.5 inches at Sedona and 31 inches at the South Rim of the Grand Canyon were recorded. Heavy snows isolated Page and other Northern Arizona communities for approximately two weeks. People on the Navajo reservation were instructed to use ashes from their stoves to write distress signals in the snow that could be spotted from the air. The total disaster cost to the State of Arizona was \$2.2 million in 1997 dollars. A total of eight people died of exposure (DEMA, 2009).



Snow damage at Southern Union Gas Station in Flagstaff, AZ (12-19-1967)  
Source: NAU Cline Library, Online at: <http://archive.library.nau.edu/cdm/singleitem/collection/cga/id/17991/rec/16>

The table below summarizes snowfall related historic records for Arizona since 1950.

**Table 10: Snowfall Records in Arizona**

Event	Amount (Inches)	Date	Location
Record Max Yearly	400.9	1972-73	Sunrise Mountain
Record Max 1-Day	38.0	Dec. 14, 1967	Heber Ranger Station
Highest Average Annual	243.0	--	Sunrise Mountain
Source: Office of the State Climatologist for Arizona (valid as of 2013)			

## PROBABILITY/EXTENT

The probability of a winter storm with significant snow accumulation is high for most of the North Region, and small areas within the Central and South Regions that are located above 5,000 feet in elevation. The Planning Team chose to use two data sets to depict the probability and extent of the snow hazard. The first is a nationwide snow climatology statistics data set compiled by the then National Climatic Data Center<sup>1</sup> using 1948-1996 records from weather stations across the country<sup>2</sup>. From this data, the NCDC developed one-, two-, and three-day, 10-, 25-, 50- and 100-year recurrence interval snow depth estimates for each of the statistically eligible<sup>3</sup> stations. The second source of data is maintained by the NCEI and reports the maximum one-day, two-day, and three-day duration snow depths for weather stations across the nation, through water year 2006. The NCEI data was processed by the Planning Team using GIS tools, to develop zones of maximum snowfall depth for each of the one, two, and three-day durations. Bordering gage stations in California, Nevada, Utah, Colorado, and New Mexico were used to ensure that no boundary effects were created at the Arizona borders. The zonal generation results, along with the NCDC 100-year recurrence interval probabilities for the three-day durations.

## WARNING TIME

The National Weather Service is able to provide warning for an impending winter storm that is typically 24-48 hours or more. The National Weather Service in Flagstaff uses the following criteria for issuing warnings about winter storm weather:

### Blizzard Warning

Sustained winds or frequent gusts of 35 mph or more, AND visibility frequently below 1/4 mile in considerable snow and/or blowing snow, AND above conditions are expected to persist for three hours or longer.

<sup>1</sup> The NCDC is now the National Centers for Environmental Information, and is a part of the US Department of Commerce, National Oceanic and Atmospheric Administration.

<sup>2</sup> NOAA/National Climatic Data Center, 1998, *United States Snow Climatology*, TD-9641

<sup>3</sup> Those stations with sufficient continuous data.

## Winter Storm Warning

Issued when more than one winter hazard is involved producing life-threatening conditions, such as a combination of heavy snow, strong winds producing widespread blowing and drifting snow, freezing rain, or wind chill. Tables 11 and 12 provide Snow Warning and Snow Advisory Criteria.

**Table 11: Heavy Snow Warning Criteria**

Elevation	Inches / 12 Hr	Inches / 24 Hr
Above 8,500 ft	12 inches/12 hrs	18 inches/24 hrs
7,000 to 8,500 ft	8 inches/12 hrs*	12 inches/24 hrs*
5,000 to 7,000 ft	6 inches/12 hrs	10 inches/24 hrs
Below 5,000 ft	2 inches/12 hrs	4 inches/24 hrs

\*(Flagstaff is located in these elevation criteria)

**Table 12: Snow Advisory Criteria**

Elevation	Inches / 12 Hr	Inches / 24 Hr
Above 8,500 ft	6 to 12 inches/12 hrs	12 to 18 inches/24 hrs
7,000 to 8,500 ft	4 to 8 inches/12 hrs*	8 to 12 inches/24 hrs*
5,000-7,000 ft	3 to 6 inches/12 hrs	6 to 10 inches/24 hrs
Below 5,000 ft	1 to 2 inches/12 hrs	2 inches/24 hrs**

\*(Flagstaff is located in this elevation criteria) \*\*or snow accumulation in any location where it is a rare event.

## Blowing Snow Advisory Criteria

Issued when visibility frequently at or below 1/4 mile.

## Wind Chill

Issued when there is a wind chill factor of minus 20°F or colder.

## Freezing Rain/Drizzle or Sleet

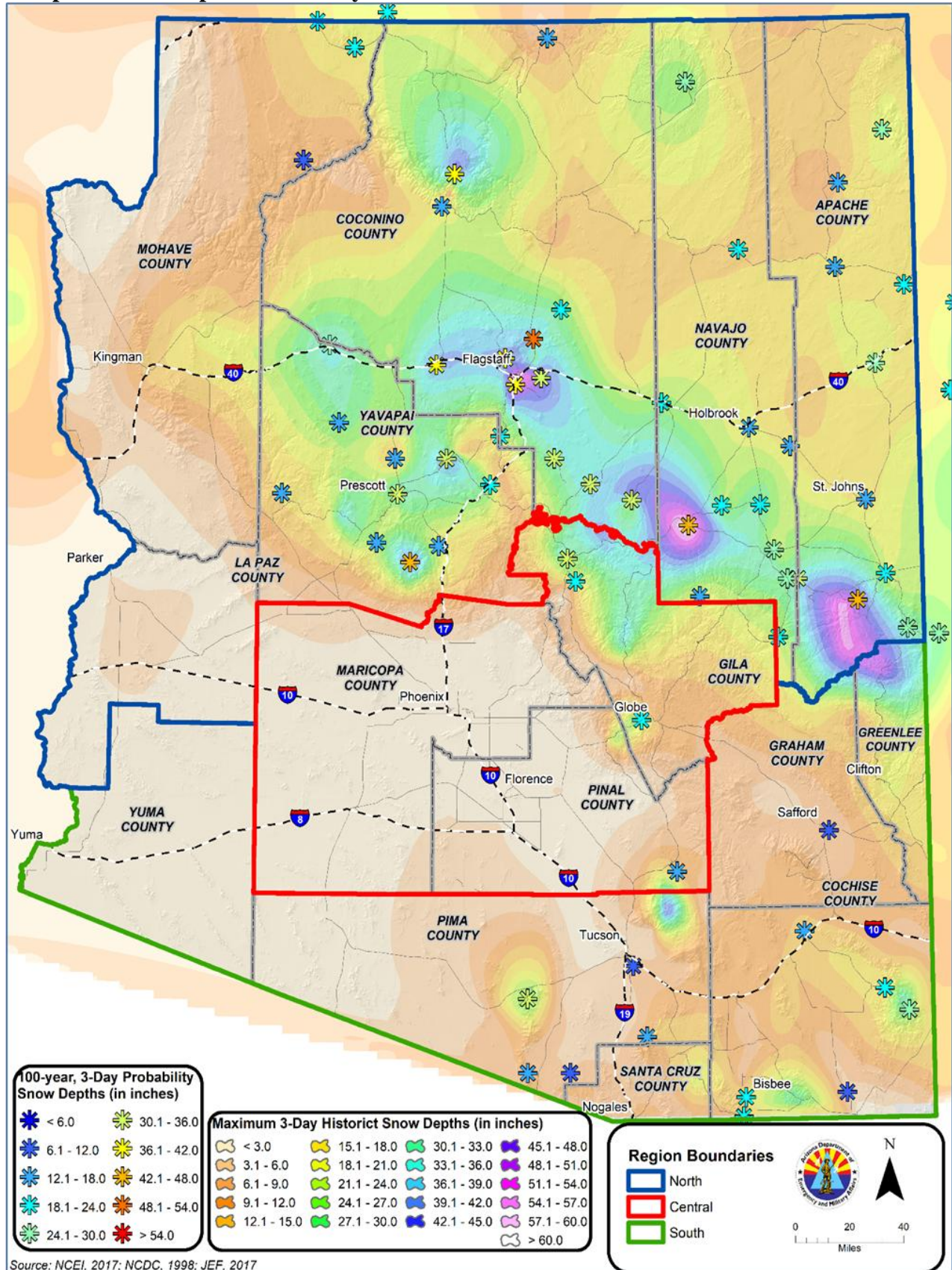
Issued when there is widespread, dangerous, and damaging accumulations of ice or sleet.

## Frost or Freeze Warning

Issued when temperatures are critical for crops and sensitive plants. Criteria is season dependent, but usually, a freeze warning is appropriate when temperatures are expected to fall below freezing for at least two hours.



**Map 53: Snow Depths for a 3-Day Event Statewide**



## **FUTURE CONDITIONS**

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### **Climate Considerations**

The NCA report (Garfin, et al., 2014) anticipates that over the duration of the 21st century, changes in the Southwest climate may result in up to a 50% decrease in April 1 snowpack due to warmer temperatures. The study also anticipates an exchange of snow producing winter storm events with more rain based storms. The current literature is silent regarding any changes to the increase or decrease of extreme snowfall events. It is anticipated that, regarding the single event based accumulations, the past may be an adequate indicator of future risks.

### **Changes in Development**

#### **North Region**

Low to moderate development of areas around established cities that are generally located north of the Mogollon Rim such as Flagstaff and Show Low, is expected over the next five years. Increases to traffic and population numbers being exposed to winter storm effects will increase the overall risk in these areas.

#### **Central Region**

Anticipated development and growth associated with most of the Central Region areas is not expected to be significantly impacted by the risk of winter storm, primarily due to the low elevations, lack of history and low probability of damaging storm events. The only exceptions to this may be areas around Payson and Globe in Gila County. The increased risk is low however, as both areas are not anticipated to experience significant growth over the next five years and the snow related hazard is moderately low.

#### **South Region**

Similar to the Central Region, snow related risks to anticipated growth in the South Region are minimal as most of the anticipated growth areas (Tucson Metropolitan area) are not at risk to snow storms.

## **VULNERABILITY ASSESSMENT**

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From a historical perspective, both human and infrastructure losses could be expected with a major winter storm event, and especially regarding traffic accidents and human exposure. Vulnerability of state-owned buildings and infrastructure exists in the form of potential for roof collapse or other damages associated with excessive snow-loads; however, estimation of potential losses to state-owned structures and buildings is difficult and would require detail analysis of the load-bearing capacities and design standards used when the buildings were constructed. Instead, a more generalized approach will be used to estimate the number of potentially vulnerable structures and their exposed value.

Freestone (2006) conducted research on the climatology of snow loads for Arizona and the use of ground snow load estimates in the structural design of buildings located in areas where snow loading can be a factor. One product of the research was a statistical analysis of snow data to produce 30-year and 50-year (3.33% and 2.0% annual chance of exceedance) probability

estimates of extreme event ground snow loads for gage locations throughout Arizona. These recurrence intervals are specified for use by modern building standards.

Freestone also noted that ground snow loads that are less than 12 pounds per square foot (or approximately 18-inches of snow depth) are considered negligible for buildings constructed using modern building codes. Accordingly, only state-owned facilities exposed to 50-year ground snow depths of greater than 18-inches will be considered as vulnerable, and no attempt to estimate losses will be made. It is noted that through inspection of the 50-year depths map, the majority of the Central and South Regions are not expected to produce winter storm snow depths greater than the 18-inch threshold.

For this Plan, all the state's population is considered exposed to some form of winter storm event and is reported as such in the following discussions. It is recognized, however, that winter storms in the North Region pose the most significant threat

## **North Region**

The North Region has the greatest vulnerability to winter storm due to the overall history of deeper snow depths, and exposure of population and state-owned buildings. It is noted, that nearly all the historic winter storm related traffic deaths and injuries have occurred in the North Region stretches of I-17 and I-40, and other major highways that pass through the region.

### **State-Owned CFI Exposure and Loss Estimates**

A total of 654 state-owned CFI, or 100% of the statewide exposure, are located within an area with a projected 50-year ground snow load depth of 18 inches or more. The exposed facilities represent \$281.7 million in replacement value. No losses are estimated.

### **Vulnerable Population Groups**

The entire 2015 estimated population of 772,157 people are considered to be exposed to winter storm events, with the population groups located above 5,000 feet in elevation being most vulnerable. The exposed sub-group populations include 177,450 persons (23.0% of region total) under 18 years of age, 158,170 persons (20.5% of region total) older than 65, 163,483 persons (21.2% of region total) living at or below poverty level, and an LEP population of 56,625 (7.3% of region total).

### **Local Jurisdiction Vulnerability**

Apache, Coconino, Navajo, and Yavapai Counties address winter storm in each of their mitigation plan's risk assessment. Conclusions of the vulnerability analysis are similar to what is presented in this Plan and no specific losses or critical facility exposures are made. The Coconino Plan estimated a general annual loss of \$500,000 could be expected, at least one fatality and multiple injuries could result. The other plans all noted that past events were likely to be indicative of potential future losses in terms of infrastructure and human safety.

### **Specific Areas of Concern**

Interstates 17 and 40 are major transportation corridors that receive year-around heavy use by the traveling public and commercial long-haul truckers. Snow and ice associated with winter events has been the leading cause of deaths and injuries related to winter



storms and continues to be a significant concern. Another concern is the number of remote populations that can easily become isolated and stranded for weeks by heavy snow events, with a particular focus on the Hopi and Navajo Nations.

## Central Region

The Central Region is considered the second most vulnerable to winter storm events, primarily due to the populations and infrastructure located in the upper elevations of Gila County, including Payson, Pine, Strawberry, Young, and the Miami-Globe area.

### State-Owned CFI Exposure and Loss Estimates

None of the 3,464 state-owned facilities representing \$9 billion in replacement value are exposed to 50-year ground snow loads of 18-inches or more, and no losses are estimated.

### Vulnerable Population Groups

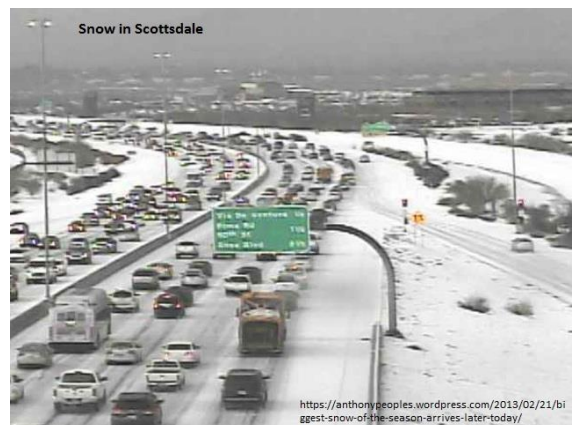
The entire 2015 estimated population of 4,604,414 people are considered to be exposed to some level of winter storm, with the highest risk areas being those parts of the region generally located above 5,000 feet in elevation. The exposed sub-group populations include 1,216,158 persons (26.4% of region total) under 18 years of age, 618,612 (13.4% of region total) persons older than 65, 748,257 persons (16.3% of region total) living at or below poverty level, and an LEP population of 306,961 (6.7% of region total).

### Local Jurisdiction Vulnerability

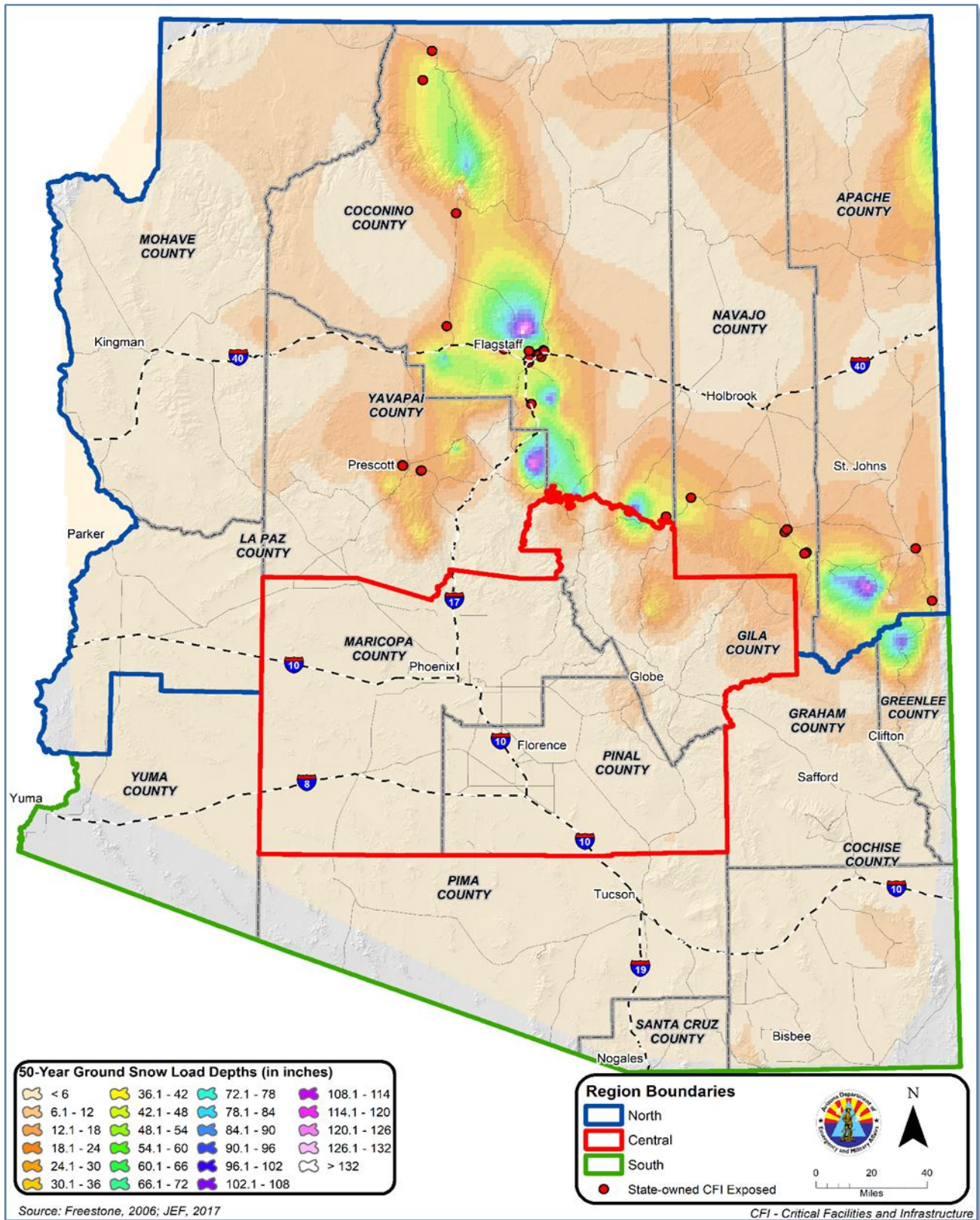
Gila County is the only Central Region county to address winter storm in their mitigation plan risk assessment. Conclusions of the vulnerability analysis are similar to what is presented in this Plan and no specific losses or critical facility exposures are made. The Gila Plan noted that past events were likely to be indicative of potential future losses in terms of infrastructure and human safety.

### Specific Areas of Concern

The most notable areas of concern for the Central Region include the remote populations and developments located along the Mogollon Rim area in Gila County becoming isolated or cut-off for significant periods of time due to heavy snow. It is also notable that although rare, small amounts of snow and ice in the urbanized Phoenix Metropolitan Area can cause businesses and schools to shut down due to lack of equipment or capacity to deal with snow covered streets and roadways, and a general public that is unfamiliar with winter driving conditions and hazards.







**Map 54: Snow Load Depths Statewide**

## South Region

The South Region is considered the least vulnerable to winter storm due to the lowest historic snow amounts and exposed population and facilities. The only notable exceptions include the higher elevation portions of Graham and Greenlee Counties, the small community of Summerhaven at the top of Mount Lemmon, and areas near the Dragoon Mountains in Cochise County.

### State-Owned CFI Exposure and Loss Estimates

None of the 1,505 state-owned facilities representing \$5.2 billion in replacement value, are exposed to 50-year ground snow loads of 18-inches or more, and no losses are estimated.

### Vulnerable Population Groups

The entire 2015 estimated population of 1,458,367 people are considered to be exposed to winter storm events. The exposed sub-group populations include 354,191 persons (24.3% of region total) under 18 years of age, 242,700 (16.6% of region total) persons older than 65, 268,372 persons (18.4% of region total) living at or below poverty level, and an LEP population of 306,961 (6.7% of region total).

### Local Jurisdiction Vulnerability

None of the South Region counties included winter storm in their risk assessments.

### Specific Areas of Concern

The community of Summerhaven can quickly become isolated if the Catalina Hwy becomes impassable due to heavy snow and ice, or snow triggered mudslides and debris flows. It is also notable that although rare, small amounts of snow and ice in the urbanized Tucson Metropolitan Area can cause schools and businesses to shut down due to lack of equipment or capacity to deal with snow covered streets and roadways, and a general public that is unfamiliar with winter driving conditions and hazards.

## POTENTIAL CONSEQUENCES AND IMPACTS

### Public

The public is directly impacted by winter storm conditions. Heavy snowfalls can collapse roofs, close roads, and leave residents and travelers stranded in their homes or vehicles with potentially disastrous results like exposure, hypothermia, and carbon-monoxide poisoning. Snow, sleet and icy conditions can make driving treacherous and is a leading cause of fatalities and injuries on the northern and higher altitude interstates and highways of the state. Associated power outages can leave homes, businesses, and others without heat or water for days or possibly longer.

### Property/Facilities/Infrastructure

Properties and structures may be vulnerable to roof damage or collapse during severe winter storms due to heavy snow. Roads can become damaged by heavy snowfall and require repair. Public and private road clearing can be expensive and even dangerous in steep, mountainous

areas that are susceptible to avalanches. Power and cable outages can also occur from heavy snowfall and ice accumulation on overhead lines causing damage to the wires or breaking wooden poles. Air traffic can become grounded for significant periods of time until runways can be cleared.

## **Responders**

Incident responders face the same threats as the general public, but on a more significant and probable level, as they are often directly exposed during the worst part of the storms. Responders can be hurt while responding to, or investigating, traffic accidents, by collision from other drivers who are unaware of the crash due to low visibility or loss of control due to poor road conditions. Responders also face injury when accessing victims in vehicles that may have driven off the roadway into areas that have rough or steep terrain. The chance of injury, illness, and death is significantly elevated for responders during winter storm events. Other threats to responders may include exhaustion, hypothermia, and exposure or physical injuries due to extremely cold temperatures. Additionally, significant snow storms can hinder both ground and air emergency service vehicles from responding to accidents or other emergencies.

## **Continuity of Operations/Delivery of Services**

The performance and delivery of services may easily be hindered during a winter storm event due to damaged, closed and impassable roads that prevent employees from getting to their place of work, or damaged buildings that displace employees and functions served by the damaged building. Power outages can also affect the ability of the state to provide services, and especially at a local level. Access to remote areas of the state can be significantly hindered, and may cause small, isolated jurisdictions to shut down without support or assistance from neighboring jurisdictions to remain operational and self-sustaining during and after a significant event.

## **Environment/Cultural**

Typically, there is not a significant risk posed to the environment from the effects of winter storms. There is a concern for areas that use salt to de-ice roadways as it can wash into lakes, streams, and seep into groundwater supplies. The salt is also harmful to plants. It is estimated that about 137 pounds of salt per person annually is used in the United States to melt ice<sup>1</sup>, the equivalent of 22 million tons.

Other substances have been used on roads to lessen the environmental impacts. Flagstaff, for example, has experimented with using volcanic cinders on roads, as well as chemical de-icers such as 'Ice Slicer.' The chemical de-icers are effective and reduce accidents, but they also impact the environment. Agencies including Coconino County and ADOT have found that chemical de-icers kill Ponderosa Pines<sup>2</sup>. As trees become ill, they turn into roadside hazards as

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<sup>1</sup> Stromberg, J. (2014). *What Happens to All the Salt We Dump On the Roads?* Smithsonian.com <http://www.smithsonianmag.com/science-nature/what-happens-to-all-the-salt-we-dump-on-the-roads-180948079/#LsYdFBKwr4MhIbRk.99>

<sup>2</sup> Sevigny, M. (2015). *Snow Season in Flagstaff Pits Ice-Free Roads Against Ponderosa Pines*. KJZZ 91.5. <http://kjzz.org/content/241486/snow-season-flagstaff-pits-ice-free-roads-against-ponderosa-pines>

they die and become vulnerable to falling. This prompted some agencies to switch back to the use of cinders as they were locally available and caused less harm to the environment.

The cultural impacts due to a winter storm are generally limited to temporary closures of culturally significant facilities during or after events, or the potential to permanently displace a cultural group due to structure damage.

### **Economic/Financial Condition of Jurisdiction**

Responding to severe winter events can be costly in terms of both deployed resources and human life and safety. Severe winter storms affect transportation, utilities, agriculture and the supply of basic subsistence. Significant damage to these areas can cause economic hardship through loss of revenue, business and increased costs of necessary supplies to a shortage of supply. Damage and/or loss of crops and livestock can also result in revenue and supply losses.

### **Public Confidence in Jurisdiction's Governance**

As with all disaster events, the swiftness of response and recovery, as well as dissemination of information about the event, will have a direct impact on the public's confidence in the jurisdiction's governance. The impacts of winter storms such as road or facility closures or loss of power, can erode the public confidence if the situations linger or take what the public might perceive as too long to repair.

### **Cascading/Secondary Impacts**

Secondary effects of winter storms can include triggering of landslides or mudslides, avalanche, erosion of hillsides due to loss of trees from avalanches, springtime flooding from large winter snowpack, winter flooding due to rain-on-snow events, power outages, and the potential for hypothermia from exposure and disruption of heat sources. Lower elevation desert areas may experience runoff from rapid snowmelt following winter storm events that may lead to flooding and erosion.

## **RESOURCES**

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### **Sources**

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## SECTION 5: MITIGATION STRATEGY

### SECTION CHANGES

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The mitigation measures are no longer presented in table format.

### MITIGATION GOALS AND OBJECTIVES

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The mitigation goal and objectives were reviewed to ensure they remain illustrative of the statewide mission and responsibilities related to mitigation. They were revised to reflect our dedication to building capabilities and resilience, while involving the Whole Community. The goal and objectives are as follows:

#### **Hazard Mitigation Goal**

Increase resilience throughout the State of Arizona by reducing the vulnerability of people and property to natural and human-caused hazards.

#### **Objectives**

1. Empower people, families, and businesses to reduce their vulnerability
2. Increase public and government awareness regarding Arizona's hazards and risks
3. Promote hazard mitigation throughout Arizona
4. Ensure the wellbeing of Arizona's citizens and visitors by lessening the impact of hazards
5. Reduce the vulnerability of critical facilities and infrastructure from natural and human-caused hazards
6. Identify and pursue funding sources for hazard mitigation projects
7. Identify and reduce the number of repetitive loss and severe repetitive loss properties

### MITIGATION MEASURES

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The mitigation measures outlined in this Plan are large scale overarching measures that support the communities of Arizona. The hazards identified in the risk assessment are inclusive of all major hazards, and therefore encompasses the major risks and vulnerabilities of local, county, and tribal jurisdictions. The State of Arizona, in partnership with local, county, and tribal governments, utilizes a holistic, decentralized approach for hazard mitigation in an attempt to attain the common goal of reducing and/or eliminating the impact from hazards resulting in increased resilience.

The 2013 Plan's Mitigation Strategy was evaluated to determine the status and disposition of the mitigation measures. The possible dispositions were, delete, revise, and remain in the Plan. The 2013 Plan's mitigation measures with status and disposition and supporting information are located in Appendix A.

The mitigation measures included in this Plan update were prioritized using a model that allowed lead agencies to prioritize the mitigation measures they are responsible for implementing.

Agencies and departments have varying levels of staff and finances, and may have different leadership priorities. New measures within the mitigation strategy were categorized with high, medium, or low designations based on which measures would be completed first to last. The strategies agencies were encouraged to use to prioritize their mitigation measures include, in order, but are not limited to:

- Direct impact on life
- Direct impact on property
- Long-term solution
- Benefit vs. cost
- Environmentally & technically sound
- Repetitive & severe repetitive loss properties
- Availability of funds
- Availability of staff
- Agency leadership priorities

**Lead Agency: Department of Emergency and Military Affairs Division of Emergency Management (DEMA)**

**1. Hazard Addressed:** All climatic hazards

**Action:** Promote and disseminate climate change research and workshop information and data to state agencies, local, county, and tribal jurisdictions in order to enable all parties to prepare for the potential future conditions of the state.

**Priority:** High

**Estimated Completion:** Ongoing

**Potential Funding Source:** Existing Staff/Budget

**Objective Satisfied:** 1, 2, & 3

**Lead Agency: Arizona Department of Water Resources (ADWR)**

**2. Hazard Addressed:** Flooding

**Priority:** High

**Action:** Assist local jurisdictions in acquiring, or otherwise mitigating, property located in the 100-year floodplain, beginning with repetitive loss properties.

**Estimated Completion:** Ongoing/Annually

**Funding Source:** Existing Staff/Budget

**2013 Update:** Some local jurisdictions have acquired homes in the floodplain that was converted to open space. ADWR investigates NFIP compliance of repetitive loss properties and discusses mitigation opportunities with local jurisdictions. DEMA

continues to work with local jurisdictions and solicit grant applications in order to acquire eligible repetitive loss properties.

**2018 Update:** ADWR continues to evaluate floodplain management programs for NFIP compliance including for repetitive loss properties. The DEMA State Hazard Mitigation Officer conducts outreach and presentations to counties at the beginning of each calendar year to educate and encourage the submittal of FEMA HMA grant application.

**Objective Satisfied:** 4 & 7

## **2.1 Hazard Addressed:** Dam Failure

**Action:** Provide information to county and local emergency management and floodplain management officials regarding the status, potential hazards, and risks associated with deficient dams to ensure they make better informed decisions regarding planning and development.

**Priority:** Medium

**Estimated Completion:** Ongoing/Annually

**Potential Funding Source:** Existing Staff/Budget

**2013 Update:** ADWR maintains a listing of deficient dams and requires updated Emergency Action Plans from all owners of high and significant hazard potential dams. Specifically, ADWR and the dam owners have made local entities potentially affected by Magma Dam in Pinal County (repairs underway and expected to be completed in 2013), Fredonia Dam in Coconino County, Powerline Dam in Pinal County (repairs underway and expected to be completed in 2013), and Cook Reservoir Dam in Graham County are each made aware of potentially elevated risks due to deficiencies.

**2018 Update.** ADWR continues to require updated EAPs for all high and significant hazard potential dams. ADWR maintains a database of all jurisdictional dams, and this database identifies those dams that have safety deficiencies. The construction of the repairs at Magma Dam in Pinal County is complete and the safety deficiency is removed. Interim dam safety measures have been implemented at Powerline Dam in Pinal County. The owner is currently designing measures that will replace the dam with a conveyance structure. ADWR through DEMA funded a project to prepare an EAP for Fredonia Dam in Coconino County. There is a design project currently underway to address the safety deficiencies at Fredonia Dam.

**Objective Satisfied:** 1, 2, 4, & 5

## **2.2 Hazard Addressed:** Dam Failure

**Action:** Identify adequate funding sources within the dam repair program, which is designed to assist the state and the dam owners in the protection of life and property. Report to the Director of ADWR.

**Priority:** High

**Estimated Completion:** Ongoing/Annually

**Potential Funding Source:** Existing Staff/Budget



**2013 Update:** ADWR manages Dam Repair Funds and routinely makes grants to owners of unsafe dams. Two grants provided in 2009. Funding was provided and work has been completed on the engineering design and plans for rehabilitation of Millet Swale Dam in Navajo County and for removal of Cook Reservoir Dam in Graham County. Both projects currently seek funding for construction costs. Due to the economic recession and legislative sweeps of the Dam Repair Fund, no additional dam projects have been funded since 2009. Recent increases to ADWR's Dam Safety permit and inspection fees may make funding for additional projects in the near future.

**2018 Update:** ADWR used a grant from DEMA to hire a consultant to develop and Emergency Action Plan for Fredonia FRS. ADWR is in discussions with Cochise County to address safety deficiencies at LCWUA Dam in Cochise County. ADWR is funding a project to assess the stability of Frye Mesa Dam under hydraulic and seismic loading conditions.

**Objective Satisfied:** 1 & 6

### **2.3 Hazard Addressed:** Flooding

**Action:** Continue to encourage and educate local officials and renters who live in areas that are flood prone to acquire flood insurance through the NFIP.

**Priority:** Medium

**Estimated Completion:** Ongoing

**Potential Funding Source:** Existing Staff/Budget

**2013 Update:** ADWR promotes flood safety and awareness through the Community Assistance, National Flood Insurance and RiskMAP Programs. Staff created two outreach brochures for distribution to communities and residents: "Manufactured Homes, Recreational Vehicles, Park Trailers and Floodplains" and "Wildfire and Flood Risks."

**2018 Update:** ADWR promotes community compliance, training and outreach regarding the National Flood Insurance Program. Staff conducted training workshops, Community Assistance Visits, Community Assistance Contacts, and provided general technical assistance to incorporated and unincorporated areas throughout Arizona.

**Objective Satisfied:** 1, 2, 3, & 4

### **2.4 Hazard Addressed:** Flooding

**Action:** Encourage communities to begin or continue participation in the Community Rating System (CRS) program. The program offers credit for various activities that potentially reduce flood damages and assist property owners in receiving reduced insurance premiums.

**Priority:** Low

**Estimated Completion:** Ongoing

**Potential Funding Source:** Existing Staff/Budget

**2013 Update:** ADWR discusses the benefits of the CRS program and encourages participation during Community Assistance Program meetings with NFIP communities.

Currently, 25 communities participate in the CRS program, and two more are considering joining.

**2018 Update:** 26 communities have earned enough CRS credits receive discounted flood insurance premiums for residents.

**Objective Satisfied:** 1, 2, 3, & 4

## **2.5 Hazard Addressed:** Dam Failure

**Action:** Coordinate with county/community emergency management and floodplain management officials to provide information regarding the locations and potential hazards of existing dams so communities can make better informed development decisions.

**Priority:** Low

**Estimated Completion:** Ongoing/Annual

**Potential Funding Source:** Existing Staff/Budget

**2013 Update:** ADWR regularly inspects all jurisdictional dams. ADWR will in the near future begin a project of low-cost flood inundation mapping using the software developed by the US Department of Homeland Security. This work will greatly increase the number of dams, including those not without development downstream currently, having identified flood inundation limits in the event of dam failure and thereby provide information for informed decision-making which does not currently exist.

**2018 Update:** ADWR continues to communicate and coordinate with county and local emergency management and floodplain managers in order to ensure the awareness of existing and new potential hazard areas. ADWR is in discussions with the owners of two high-hazard dams to provide financial assistance to develop EAPs for these structures (Central Detention and Colter Dam).

**Objective Satisfied:** 1, 2, 4, & 5

**Lead Agency:** Arizona Geological Survey (AZGS)

## **3. Hazard Addressed:** Flooding

**Action:** Investigate areas with the potential for debris flows and flooding in the post-fire environment & identify high-risk areas for incorporation into mitigation plans and to target areas for mitigation activities.

**Priority:** High

**Estimated Completion:** Ongoing/Multi-year project

**Potential Funding Source:** FEMA RiskMap program

**2013 Update:** Recent mapping in Gila County. Released report evaluating debris flow potential in the post-wildfire environment in Gila County. Research into post-fire debris flows is ongoing. Funds for dedicated studies are lacking. AZGS recently published the Southwest Wildfire Hydrology & Hazard Workshop Proceedings, summarizing the state of knowledge of post-wildfire debris flows in the Southwest.

**2018 Update:** A recently completed study for Coconino County identified areas potentially at risk from post-wildfire debris flows. Two of the identified areas were then studied in detail to estimate risks and to identify potential mitigation options. It was funded by FEMA's RiskMap program. Other research into post-fire debris flows is ongoing, but funds for dedicated studies are lacking.

**Objective Satisfied:** 1, 2, 3, 4, & 5

### 3.1 **Hazard Addressed:** Flooding

**Action:** Conduct surficial geologic mapping to evaluate piedmont areas that may be prone flooding. Make the resulting map products available on the AZGS document repository for use in planning efforts at the local, county, and tribal levels.

**Priority:** Medium

**Estimated Completion:** Ongoing

**Potential Funding Source:** Existing Staff/Budget

**2013 Update:** Several reports and maps published. Released numerous geologic quadrangle maps showing extent of young deposits, interpretations of flood hazards. As part of the StateMap program, we continue to map and evaluate flood hazards on piedmonts. The resulting maps and reports, including several Contributed Reports are available at no charge at the AZGS online document repository ([repository.azgs.az](http://repository.azgs.az)).

**2018 Update:** Evaluating flood hazards on piedmonts continues

**Objective Satisfied:** 1, 2, & 7

### 3.2 **Hazard Addressed:** Fissure

**Action:** Conduct earth fissure planning map briefings for state and local agencies whose responsibilities are affected by fissures.

**Priority:** Low

**Estimated Completion:** Ongoing

**Potential Funding Source:** FEMA HMA program

**2013 Update:** Briefings for agencies associated with initial releases of earth fissure maps; continued interaction with local and state agencies. AZGS continues to communicate with local and state authorities about earth fissures. Civil authorities are notified upon the release of new earth fissure maps. At the onset of each monsoon season, we issue a reminder to county authorities regarding earth fissures and request information on any new or ongoing development.

**2018 Update:** No Change. The previous process remains in place and the effort is ongoing.

**Objective Satisfied:** 2 & 5

### 3.3 **Hazard Addressed:** Fissures, Flooding, and Landslides

**Action:** Perform outreach to deliver awareness of geologic hazards - earth fissures, landslides, debris flows, and flash floods via workshops, online resources, media, and other outreach avenues through AZGS Geologic Extension Service.

**Priority:** Medium

**Estimated Completion:** Ongoing

**Potential Funding Source:** FEMA HMA program

**2013 Update:** Fissure and earthquake outreach programs are active. AZGS continues to develop print and web outreach products describing geologic hazards in Arizona. In 2012, and in partnership with DEMA, we hosted the Great Arizona ShakeOut with 62,500 Arizonans participating. Our Arizona Shakes Earthquake Outreach program is our most successful hazard awareness program due to annual funding from the National Earthquake Hazard Reduction Program. Funding for other geologic hazard awareness programs are wholly lacking.

**2018 Update:** Expanded outreach by partnering with DEMA to promote the Great Arizona ShakeOut program to municipal, county, and tribal emergency management offices, health authorities, volunteer organizations, K-12 education community, and the public. Funding for other outreach initiatives continues to be an issue.

**Objective Satisfied:** 1 & 2

### 3.4 **Hazard Addressed:** Earthquake

**Action:** Distribute earthquake hazard information via hard copy and internet (including posters and presentations, monitoring and activity updates, etc).

**Priority:** Low

**Estimated Completion:** Ongoing

**Potential Funding Source:** FEMA HMA program, NEHRP, AZGS

**2013 Update:** Working on web and print materials. AZGS continues to aggressively pursue an earthquake hazard outreach program. Recent outreach publications include: earthquake preparedness brochures, Arizona is Earthquake Country Down-to-Earth text, and videos exploring Quaternary faults in Arizona. With DEMA we hosted the Great Arizona ShakeOut in October 2012. The second Great Arizona ShakeOut is scheduled for October 2013; as of May 26, 2013, nearly 10,000 Arizonans are enrolled in the program. NEHRP funding in 2014 is at risk. The loss of funding will adversely impact AZGS efforts to alert the Arizona public to earthquake hazards.

**2018 Update:** In 2015, enrollment was 124,000. In 2016, enrollment dropped to 65,500. NEHRP funding was pulled for several years, critically impacting our earthquake preparedness program. We are likely to receive \$31,000 for FY-2018, with AZGS dollar-for-dollar match; we'll invest more than \$62,000 in earthquake outreach in 2017-2018.

**Objective Satisfied:** 1 & 2

### 3.5 **Hazard Addressed:** Earthquake

**Action:** Investigate quaternary (young) faults to estimate the time since the most recent event, average recurrence intervals or slip rates and to estimate paleoearthquake magnitudes. This information can be used for seismic hazard assessments, including probabilistic earthquake hazard maps, which in turn can be used to plan mitigation projects.



**Priority:** Low

**Estimated Completion:** Ongoing

**Potential Funding Source:** US Geological Survey, StateMap Program, ADOT

**2013 Update:** Some mapping complete. Investigated one quaternary fault zone in western AZ in 2007-08 as part of mapping project for ADOT; discovered on quaternary fault zone north of Prescott and team is mapping two other as part of StateMap program. AZGS monitors seismic activity in Arizona with the Arizona Broadband Seismic Network. Where encountered as part of AZGS's StateMap program, faults are mapped and characterized. A new Quaternary fault map is in a preliminary state of construction. Funding for detailed characterization of Quaternary faults has not been procured.

**2018 Update:** Mapping and revising previously documented faults continues through the StateMap program. Funding for detailed characterization of quaternary faults has not been procured.

**Objective Satisfied:** 1 & 2

### 3.6 **Hazard Addressed:** Landslide

**Action:** Coordinate research priorities to develop a predictive understanding of landslide processes & triggering mechanisms. Make the resulting information available to local, county and tribal entities to aid in planning and mitigation efforts.

**Priority:** Medium

**Estimated Completion:** Ongoing

**Potential Funding Source:** US Geological Survey

**2013 Update:** Some debris flow mapping in place. Mapped young debris flow deposits in Tucson area with funding from local flood control district and AZGS; investigations of triggering mechanisms underway. As part of the FEMA-funded Arizona Hazards Viewer, AZGS is making some progress on understanding where slope and geologic conditions are conducive to landslides in Arizona. But much more needs to be done and dedicated funding stream identified for additional study.

**2018 Update:** Debris-flow mapping is part of every StateMap funded map. Many undocumented landslides were found while developing the landslide database. Funding is needed to better document and understand these landslides. The greatest threats from landslides, however, are from disturbed areas such as those areas burned by wildfires. Exploring potential funding sources.

**Objective Satisfied:** 1 & 2

### 3.7 **Hazard Addressed:** Fissure

**Action:** Identify and map known fissures across the state. Publish the maps and make available at AZGS's Earth Fissure Viewer. This information can aid the local, county, and tribal entities in their planning and mitigation efforts.

**Priority:** Low

**Estimated Completion:** Ongoing

**Potential Funding Source:** State Budget

**2013 Update:** Completed earth fissure mapping in Maricopa and Pinal Counties, made maps available to public. Seventeen maps published since 2007. Mapping of earth fissures is ongoing. Twenty-two of the original earth fissure study areas have been mapped and the maps are published. All published earth fissure maps are available at AZGS's Earth Fissure Viewer. Over the next several years, the earth fissure program will transform from mapping fissures to monitoring fissure development.

**2018 Update:** Mapping and monitoring of earth fissures is ongoing and maps are updated as needed. Mapping of all study areas in Cochise County has been completed and published. New study area maps in Pima and Pinal County have been published bringing the total number of fissure study area maps to twenty-six. Updated versions of active study areas in Pinal, Maricopa, and Cochise County have been released.

**Objective Satisfied:** 1 & 2

### 3.8 NEW MITIGATION ACTION

**Hazard Addressed:** All natural hazards

**Action:** Add the GIS layers from 2018 state hazard mitigation plan risk assessment maps to the natural hazards viewer.

**Priority:** High

**Estimated Completion:** 2020

**Potential Funding Source:** Existing Staff/Budget

**Objective Satisfied:** 1, 2, & 3

### Lead Agency: Arizona Department of Environmental Quality (ADEQ)

#### 4. **Hazard Addressed:** Hazardous Materials

**Action:** Manage an online database for Hazardous Materials and Extremely Hazardous Chemicals in which facilities in Arizona upload Tier II information for viewing by Fire Departments and Local Emergency Planning Committees for response and planning activities to mitigate against HazMat incidents.

**Priority:** High

**Estimated Completion:** Ongoing/Annually

**Potential Funding Source:** ADEQ

**2013 Update:** By the end of this year's reporting cycle (March 1, 2013) 4,100+ Arizona facilities have entered their Tier II information into the database.

**2018 Update:** 4,100+ facilities still enter information into the database. Database is maintained by ADEQ and updated by facilities on an annual basis.

**Objective Satisfied:** 1, 2, & 5

#### 4.1 **Hazard Addressed:** Hazardous Materials

**Action:** Distribute funds to the Local Emergency Planning Committees (LEPCs) to support HazMat planning, training, and equipment. The LEPCs have Response Plans in the event of a HazMat incident. The HazMat training is for first responders and the equipment enhances the County HazMat Teams.

**Priority:** High

**Estimated Completion:** Ongoing

**Potential Funding Source:** HMEP program

**2013 Update:** Currently being implemented.

**2018 Update:** Grant fund letters have been sent to LEPCs. HMEP awards are being processed.

**Objective Satisfied:** 5 & 6

#### **4.2 Hazard Addressed:** Hazardous Materials

**Action:** Provide consultative services, conduct and participate in workshops and coordinate development and review of plans and programs for 15 LEPC.

**Priority:** Medium

**Estimated Completion:** Ongoing

**Potential Funding Source:** ADEQ

**2013 Update:** Currently in progress.

**2018 Update:** Program is in the process of being improved. At this time, ADEQ employees are attending meetings and providing guidance.

**Objective Satisfied:** 1, 2, & 5

**Lead Agency:** Department of Forestry and Fire Management (DFFM)

#### **5. Hazard Addressed:** Wildfire

**Action:** Ensure Arizona Firewise Communities program and fire prevention information is distributed statewide. It has been repeatedly demonstrated that education is a key component in convincing the public to endorse and adopt wildland fire prevention and Firewise principles and activities.

**Priority:** High

**Estimated Completion:** Ongoing

**Potential Funding Source:** Existing Staff/Budget

**2013 Update:** All three field districts for State Forestry Divisions meet with Fire Chiefs in their respective districts monthly, quarterly and annual meetings, conference and training sessions and advocate wildland urban interface and Firewise models. The growing list of Firewise Communities in Arizona at 45 is a significant indicator of mitigation work accomplished to prevent or reduce wildfire risk.

**2018 Update:** There are now five districts under DFFM and outreach on a monthly, quarterly, and annual basis continues in order to promote the adoption of Firewise principles. The number of Firewise Communities has grown to 87.

**Objective Satisfied:** 1, 2, 3, & 4

**5.1 Hazard Addressed: Wildfire**

**Action:** Maintain GIS wildfire incident database and share data with local jurisdictions and others that may benefit from using it to identifying areas at risk and prioritize project areas based on present fuels, threat to the public, and natural resources and to track the location and progress of ongoing projects.

**Priority:** High

**Estimated Completion:** Ongoing

**Potential Funding Source:** Existing Staff/Budget

**2013 Update:** With database complete, the information is collected and updated on a yearly basis.

**2018 Update:** Information continues to be gathered as the climate, and physical and built environment continue to change and impact/alter the hazard areas.

**Objective Satisfied:** 1 & 2

**5.2 Hazard Addressed: Wildfire**

**Action:** Encourage cities, communities, and other municipalities to specify landscaping requirements based upon Firewise principles. This is necessary for those living in or owning property in the WUI or Communities at Risk to manage the fuels on their properties to reduce their risk from wildland fires.

**Priority:** High

**Estimated Completion:** Ongoing

**Potential Funding Source:** Existing Staff/Budget

**2013 Update:** Forestry Division staff conduct outreach, especially the District Forestry staff in our three districts -Tucson, So Arizona, Phoenix District in Central AZ, Flagstaff District in No Arizona. This outreach has resulted in Arizona holding one of the highest community certification rates in the nation at 45.

**2018 Update:** Outreach is now conducted in five districts - Northern in Flagstaff, Northeastern in Pinetop, Southeastern in Tucson, Central in Phoenix, and Northwestern in Chino Valley.

**Objective Satisfied:** 1, 2, & 3

**5.3 Hazard Addressed: Wildfire**

**Action:** Add requirements to building codes for fire resistive materials for new construction and additions to existing construction. One element of Statewide Strategy for Restoring Arizona's Forests: encourage community leaders to take steps to mitigate against wildfire by encouraging local implementation of WUI codes.

**Priority:** High

**Estimated Completion:** Ongoing

**Potential Funding Source:** Existing Staff/Budget



**2013 Update:** Governor's Forest Health Council work plan includes outreach to communities regarding WUI codes and Firewise practices. Provides public forums for community leaders; six communities have adopted codes.

**2018 Update:** No new communities have adopted codes but implementation and advocacy efforts continue.

**Objective Satisfied:** 4 & 5

#### **5.4 Hazard Addressed:** Wildfire

**Action:** Continue to complete wildland fuels reduction projects as appropriate and renew/revise agreements as necessary.

**Priority:** High

**Estimated Completion:** Ongoing

**Potential Funding Source:** FEMA, other federal funding

**2013 Update:** Actively prioritizing projects as federal grant funding is awarded.

**2018 Update:** No change as this is a continuous operation.

**Objective Satisfied:** 4 & 5

**Lead Agency:** State Climate Office & Arizona State University (ASU)

### **6. NEW MITIGATION ACTION**

**Hazard Addressed:** All Natural Hazards

**Action:** The State Climate Office will pull together a Natural Hazards webpage that describes Arizona's weather/climate related natural hazards and explains measures the public can take before, during and after the events to keep themselves and their property safe. Will also include links to resources for assistance before and after extreme weather events. This will be linked to Arizona State University's web pages, as many of the students at the University are from other states and may be unaware of Arizona's weather/climate hazards.

**Priority:** High

**Estimated Completion:** 2023

**Potential Funding Source:** Existing Staff/Budget

**Objective Satisfied:** 1 & 2

#### **6.1 NEW MITIGATION ACTION**

**Hazard Addressed:** All Natural Hazards

**Action:** The State Climate Office, in conjunction with Arizona State University, will create a University-wide weather webpage showing current weather conditions across the four campuses and include NWS alerts, special weather statements, watches and warnings for the area and the state. This page will link to the Natural Hazards page.

**Priority:** High

**Estimated Completion:** 2023

**Potential Funding Source:** Existing Staff/Budget

**Objective Satisfied:** 1 & 2

**Lead Agency:** Arizona Department of Agriculture (AZDA)

## 7. NEW MITIGATION ACTION

**Hazard Addressed:** All Hazards

**Action:** The AZ Department of Agriculture will publish the Arizona Secure Food Plan in order to increase awareness of food safety for producers while reducing the vulnerability of agricultural producers from natural and human-caused hazards. The Secure Food Plan will consist of three major components: secure beef, dairy, and egg plans. The goals of these plans will be to assure a continuous food supply to consumers and maintain business continuity for producers during both disease outbreaks and other emergencies that can affect agricultural products. These plans will provide for efficient and effective emergency response to maximize the movement of safe and healthy products to the market and consumer. We will provide these plans to agriculture stakeholders so that they can begin adoption of these plans in order to be better prepared for future emergencies.

**Priority:** High

**Estimated Completion:** 2023

**Potential Funding Source:** Existing Staff/Budget

**Objective Satisfied:** 1, 2, & 3

**Lead Agency:** Arizona Counter Terrorism Information Center (ACTIC)

## 8. NEW MITIGATION ACTION

**Hazard Addressed:** Cyber Terrorism

**Action:** Conduct community outreach to improve cyber resilience by educating residents, businesses, organizations, and government entities on cyber hygiene and best practices. This capability includes creating a public-facing website for cybersecurity, building a library of cybersecurity products, such as unclassified threat/incident alerting and notification products, FAQs, newsletters, and presentations, and facilitating events and presentations. Because the internet is one connected network, improving the security practices of one individual can help protect Arizona and the world.

**Priority:** High

**Estimated Completion:** Ongoing

**Potential Funding Source:** Urban Areas Security Initiative grant program

**Objective Satisfied:** 1, 2, & 3

### 8.1 NEW MITIGATION ACTION

**Hazard Addressed:** Cyber Terrorism

**Action:** Improve and expand the cyber threat/incident alerting and notification capability. This will provide timely alerts/notices of in-process and/or potential cyber threats and incidents. This will also include possible measures to prevent, detect, and respond to the threats, to residents, companies, community partners, organizations, state, local, tribal,

law enforcement, military, and other entities. This will enable the State of Arizona to potentially prevent and minimize the impact of cyber incidents.

**Priority:** High

**Estimated Completion:** 2023

**Potential Funding Source:** Urban Areas Security Initiative grant program

**Objective Satisfied:** 1, 2, & 3

**Lead Agency:** Arizona Department of Administration (ADOA)

## 9. NEW MITIGATION ACTION

**Hazard Addressed:** All Hazards

**Action:** Develop a comprehensive framework to facilitate the implementation of a standardized and sustainable Safety Management System (SMS) for all state agencies, boards, and commissions.

Core elements of this SMS involve the identification, assessment, and control of hazards at all levels. This includes those present in a specific job task or particular workspace, to those applying to a whole facility or property. In the SMS, standardized tools such as specific hazard control plans, all-hazard emergency plans, and safety training will be integrated with guidance for obtaining leadership support and increasing employee engagement.

Since the presence of guests, visitors, and customers on-site is also considered, mitigation measures taken as part of this initiative will positively affect safety and health of others in addition to state workers. Finally, because continual evaluation and sustainable improvement of the SMS will be emphasized, mitigation measures will be measurable and part of an ongoing cycle within those implementing the system.

**Priority:** High

**Estimated Completion:** 2023

**Potential Funding Source:** ADOA

**Objective Satisfied:** 1, 2, 3, & 5

### 9.1 NEW MITIGATION ACTION

**Hazard Addressed:** Terrorism - Cyber

**Action:** Building a Cybersecurity Workforce Economic Development

The State of Arizona, through the Governor's AZ Cyber Team Executive Order, will drive cybersecurity and IT related workforce economic development and education. This will be a collaborative effort that will include representatives from public, private, and education sectors.

**Priority:** High

**Estimated Completion:** Ongoing

**Potential Funding Source:** N/A

**Objective Satisfied:** 1 & 5

**Lead Agency: Arizona Department of Health Services (ADHS)****10. NEW MITIGATION ACTION****Hazards Addressed:** Infectious Disease

**Action:** ADHS will enhance and modify the states Medical Electronic Disease Surveillance System (MEDSIS) in at minimum quarterly increments. This will ensure more rapidly generated reports, searching for or pulling data from medical cases or patients, and integrating surveillance data from local, tribal, federal, and disease monitoring systems among international public health partners along the Mexico border. This will allow for timely and effective epidemiological investigations to minimize risk to the public.

**Priority:** High**Estimated Completion:** 2023**Potential Funding Source:** Public Health Emergency Preparedness grant**Objective Satisfied:** 1, 2, & 3**10.1 NEW MITIGATION ACTION****Hazard Addressed:** Infectious Disease

**Action:** Update and enhance emergency Medical Counter Measure plans, and conduct drills and exercises to ensure medical counter measure capabilities are integrated with local and tribal public health and health care coalitions. This will create capacity to cope with demands on the healthcare infrastructure and rapidly communicate risks to the public.

**Priority:** Medium**Estimated Completion:** 2023**Potential Funding Source:** Public Health Emergency Preparedness grant**Objective Satisfied:** 1, 2, & 5**Changes in Development and Priorities & Mitigation Efforts**

The state has experience steady population and job growth with impressively low unemployment rates. Arizona state personal income increased at the same rate as the US average in the third quarter 2017. The 0.7% change from the preceding quarter placed Arizona 14th among states according to the December 20 Bureau of Economic Analysis release. Along with that growth, the end of 2017 showed an approximately 8% residential building permit increase. To meet the demand for housing in Phoenix, the construction sector is expected to expand significantly, with consensus estimates calling for 6.4% job growth for the 2018.

Although Arizona continues to grow, the priorities and focus of our hazard mitigation efforts and Plan have remained consistent. The mitigation measures from the previous Plan have been for the most part either completed or in-progress. Most of the measures that are in-progress have been carried forward into this Plan for hopeful completion during the next plan cycle.



The focus of the mitigation measures has been and are likely to continue to be education and awareness related. There is also a focus on providing information and resources to implement mitigation efforts statewide.

For several years, funding has been a barrier limiting the implementation of mitigation measures throughout the state. Local, tribal and states experience difficulty in committing funding toward large projects and measures. Further, in 2004, funding for PDM was \$150 million and has at one point, dropped to approximately \$25 million. The inconsistent funding has affected mitigation statewide. Additionally, we have not been successful in obtaining FMA funding in the past. Additionally, federally declared disasters are not commonplace in Arizona and when they do occur, they do not result in large amounts of funding through FEMA's Hazard Mitigation Grant Program.

Grant funding sources are not the only challenge to implementing mitigation measures. Local jurisdictions, counties, tribal governments, and state agencies experience difficulty allocating funds for the 25% match required by federal grants. These financial constraints have prevented many from applying for mitigation funding. Arizona continues to work on identifying new funding sources and implementing the most cost effective and beneficial mitigation measures in order to overcome existing barriers to mitigation implementation.

## **STATE CAPABILITIES**

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The State of Arizona utilizes a decentralized, Whole Community approach to emergency management. The integrated emergency management program incorporates various agencies that play a role in mitigation efforts before and after a disaster. The state's primary responsibility is to support local counties and jurisdictions throughout all phases of emergency management.

According to Arizona Revised Statutes 26-305, DEMA is responsible for preparing for and coordinating emergency management activities that may be required to reduce the impact of disasters on persons or property. Additionally, DEMA shall coordinate the cooperative effort of all government agencies, including the federal government, this state, and its political subdivisions, to alleviate suffering and loss resulting from disasters.

By law, the State of Arizona, more specifically DEMA, has the responsibility to assist and protect the communities from disasters. DEMA has built an intricate emergency management enterprise and has integrated vertically and horizontally throughout all levels of government, and into the private and non-profit sectors. Many state agencies have been educated and empowered to not only understand, but implement mitigation measures. Agencies that implement statewide mitigation measures includes, but is not limited to, Arizona Department of Water Resources (ADWR), Arizona Department of Health (ADHS), Arizona Department of Environmental Quality (ADEQ), Arizona Geological Survey (AZGS), Arizona Department of Transportation (ADOT), Arizona Department of Forestry and Fire Management (DFFM), Arizona Department of Economic Security (DES), Arizona Department of Agriculture (AZDA), the University of Arizona (UA), Arizona State University (ASU), and the non-profit Team Rubicon.

### **Funding Sources**

There are many sources of funding that can be utilized for hazard mitigation. The DEMA State Hazard Mitigation Office is responsible for, and is efficient at, the administration and implementation of the Hazard Mitigation Assistance (HMA) grants, Public Assistance (PA)

grants, and the Governor's Emergency Fund (GEF). The following is a list of current and potential funding sources that may be utilized for mitigation action implementation.

#### **Hazard Mitigation Assistance (HMA) Program**

HMA grants, which include the pre-disaster mitigation (PDM) grants, Flood Mitigation Assistance (FMA) grants, and the Hazard Mitigation Grant Program (HMGP), and HMGP Post-Fire are administered by the State Hazard Mitigation Officer (SHMO). These are FEMA grants that are used to fund various mitigation projects that reduce or eliminate the impact hazards have on communities. All HMA grants may be utilized to mitigate repetitive loss and severe repetitive loss properties.

#### **Governor's Emergency Fund (GEF)**

This fund receives four million dollars annually from the State's General Fund to assist government agencies respond to and recover from emergency and disaster events. Unused funds at the end of the state's fiscal year may be used as a funding source for the implementation of mitigation projects. The Governor's Emergency Fund may be utilized for mitigation projects statewide.

#### **FEMA Public Assistance (PA)**

PA funding is federal funding provided to eligible public agencies for the repair, restoration, and possible mitigation of damaged public structures within a declared disaster area.

#### **Other Sources**

Various state agencies have an emergency management component, and, therefore, may be able to address the hazards that pose a threat to Arizona's communities. Individual state agencies have technical expertise regarding certain hazards and those agencies may appropriate funds for the implementation of mitigation projects throughout the state. Agencies have a history of developing initiatives and programs that address future conditions and reduce or eliminate the impact hazards have on communities. Additionally, there are many federal funding sources that DEMA does not administer or implement.

#### **US Dept. of Housing & Urban Development (HUD)**

Disaster recovery assistance is provided in the form of critical housing and community development to aid disaster recovery. HUD also provides funding to carry out community development activities focused economic development, revitalizing neighborhoods, and improving community facilities and services through the Community Development Block program.

#### **US Dept. of Health and Human Services (HHS)**

HHS, in coordination with the Center for Disease Control and Prevention provides funding through the Public Health Emergency Preparedness (PHEP) program. PHEP is utilized to upgrade the capacity of state and local public health jurisdictions' preparedness and response to bioterrorism, outbreaks, and other public health threats and emergencies.

### **US Army Corps of Engineers (USACE)**

The Army Corps of Engineers has rehabilitation program that is utilized to conduct emergency repair or rehabilitation of flood control works damaged by flood. Assistance does not extend to major improvements of flood control systems.

### **Natural Resource Conservation Service (NRCS)**

The NRCS has the Emergency Watershed Protection Program that undertakes emergency measures, including the purchase of floodplain easements, for runoff retardation and soil erosion prevention in an attempt to safeguard lives and property from floods, drought, and the products of erosion. The NRCS offers services, including watershed surveys and planning program to assist state, local, and tribal governments protect watersheds from damage caused by erosion, floodwater, and sediment.

### **Small Business Administration (SBA)**

The SBA offers low interest, fixed rate loans to small businesses for the purpose of implementing mitigation measures to protect their property from future disasters.

### **US Department of Homeland Security (USDHS)**

The DHS uses the Homeland Security Grant Program to help enhance the protection of Arizona's residents and critical infrastructure from potential terrorist attacks and other significant hazards.

### **National Earthquake Hazard Reduction Program (NEHRP)**

FEMA provides funding to the Arizona Geological Survey to conduct earthquake hazard awareness programs. This includes Arizona Shakeout, and the design and development of web-based and printed materials for informing and education the public.

### **US Department of Transportation (USDOT)**

USDOT offers a Hazard Materials Emergency Preparedness Grant to provide guidance, and financial and technical assistance to enhance state, tribal, and local hazardous materials emergency planning and training.

## **State Programs**

State departments have programs in place that work to mitigate the impact hazards have on state owned/operated facilities, and the entire community. These programs aim to protect property and infrastructure, save lives, and lessen the economic burden of hazards. Below are examples of state programs that work towards building a resilient state.

### Arizona Dept of Administration (ADOA) Risk Management Section

The focus of the ADOA, Risk Management Section as it relates to mitigation is to protect the State's assets from loss. Risk Management was established to provide insurance coverage to state agencies and employees for property, liability and workers' compensation losses in accordance with the statutory provisions found in ARS Section 41-621 through Section 41-625.

### Arizona Department of Forestry and Fire Management (DFFM)

DFFM is responsible for the prevention and suppression of wildfires on state and private lands, located outside incorporated municipalities, through the use of various cooperative agreements. They provide technical, educational, and financial assistance to rural communities and private land owners in the management of their forested lands. DFFM also manages the Firewise Program which promotes fire-safe landscaping and construction practices to help reduce the loss of property from wildfire. The Firewise Program minimizes the negative effects of wildfire on public life, safety, and property by promoting fire-safe landscaping and construction practices to help reduce the loss of property from wildfire.

#### Community Wildfire Protection Plan (CWPP)

The Arizona Department of Forestry and Fire Management (DFFM) works with communities in the state to analyze wildfire risk and develop CWPPs. CWPPs are a collaborative effort of local and state government representatives, in consultation with the federal government, to identify and prioritize areas for fuel reduction treatment and recommend mitigation measures that communities and homeowners can take to reduce their vulnerability to wildfires. CWPP information is often incorporated into the wildfire hazard profile section of local hazard mitigation plans as applicable. Communities with CWPPs are given priority for funding of hazardous fuels reduction projects under the Healthy Forests Restoration Act (HFRA).

All 15 counties in the State of Arizona utilize or have adopted CWPPs to varying degrees. Maricopa, Pinal, Pima, Mohave, Graham, Greenlee, Cochise, Yavapai, and Yuma counties all have county wide CWPPs. Gila County has separate northern and southern CWPPs and La Paz county has separate Desert Communities and River Communities CWPPs. Apache, Navajo, Coconino, and Santa Cruz counties have CWPPs for a few more at-risk communities within their respective jurisdictions. DFFM is currently funding research through Northern Arizona University (NAU) to evaluate CWPPs in Arizona in order to develop recommendations for best practices.

### Arizona Department of Water Resources (ADWR)

ADWR administers the Dam Safety Program and the National Flood Insurance Program (NFIP). These programs protect the public against loss of life and property by reducing the likelihood of catastrophic failure of jurisdictional dams, and to assist communities, counties and local jurisdictions that participate in the NFIP. ADWR also administers the Community Assistance Program, the Community Rating System program, and the RiskMAP program. These programs identify flood risk and promote practices to reduce risk; establishes state standards for floodplain management; and coordinates the planning,



design, and construction of flood warning systems. The department also coordinates resources and efforts with local, state, and federal entities during post-disaster flood and wildland fire emergencies. Additionally, the department is responsible for statewide NFIP coordination specifically regarding repetitive loss (RL) and severe repetitive loss (SRL) properties. Coordination includes but is not limited to collection and distribution of the most current RL/SRL property list from FEMA. ADWR coordinates education for jurisdiction officials with RL & potential SRL properties during their scheduled Community Assistance Visits.

## State Policies

There are few state level policies that directly affect mitigation and emergency management throughout the state. For the most part, local jurisdictions maintain autonomy in their ability to formulate and adopt policies that impact their communities. This is beneficial as all communities vary to a certain degree and require policies that best suit their circumstances. Additionally, research shows that the implementation of plans, policies, and procedures are most effective when the community is involved in the development and adoption process. Therefore, detailed policy information as to building and fire codes/standards and community development are available through local jurisdictions. The following are a few examples of state level mitigation policies.

### The Growing Smarter and Growing Smarter Plus Acts

The Growing Smarter and Growing Smarter Plus Acts were created to assist communities in developing strategies for dealing with population growth and preserving open space. The legislation requires cities and towns to adopt a general plan that addresses land use and circulation. Depending on population size, some cities and towns must also include environmental planning, cost of development, and water resources. The water resources component of the general plan addresses available surface, ground, and effluent water supplies and requires cities and towns to address future water demands and how current and potential water sources will supply the future demand.

### Executive Order 2015-13

The Governor of Arizona initiated the implementation of the Arizona Water Initiative through Executive Order 2015-13. Through the use of the Planning Area Process and the Governor's Water Augmentation Council, the initiative identifies key priorities, timelines, and action items needed to maintain sustainable water supplies for Arizona's future. The Planning Area Process involves ADWR working closely with 22 planning areas to identify issues that result in water demand and supply imbalances, and to develop strategies to address the issues. The Water Augmentation Council investigates augmentation strategies, explores water conservation opportunities, identifies infrastructure needs, and recommends policy direction or statutory changes that can help maintain sustainable water supplies for the future.

### Executive Order 2015-13

The Governor of Arizona initiated the implementation of the Arizona Cybersecurity Team (ACT) through Executive Order 2015-13. Experts from state, local, and federal governments, the private sector, and higher education work together to mitigate cyber threats and increase statewide preparedness. The ACT works to increase collaboration,

enhance cybersecurity workforce development and education, and increase public awareness on cybersecurity best practices.

#### **Arizona Revised Statute (ARS) 26-308**

State law under ARS 26-308 establishes that each county and incorporated city and town is charged with establishing and providing emergency management within their jurisdictions in accordance with state emergency plans and programs. State emergency plans shall be in effect within all subdivisions and jurisdictions within the state, and the governing bodies of each subdivision and jurisdiction may develop additional emergency plans in support of state emergency plans. This includes all response and recovery efforts outlined in the State Emergency Response and Recovery Plan (SERRP).

#### **Arizona Revised Statute (ARS) 28-910**

State law under ARS 28-910 charges that a driver who drives a vehicle on a public street or highway that is barricaded due to being temporarily covered by rise in water level from groundwater or overflow, is liable for the expenses of any emergency response that is required to remove any driver or any passenger in the vehicle should the vehicle become inoperable. This statute should serve as a deterrent to prevent vehicle operators from driving through flooded areas.

#### **ADWR Substantive Policy Statements**

ADWR Substantive Policy Statements are advisory only, and do not impose additional requirements or penalties on regulated parties. This includes the policy on the Development of Flood Control Plans, which was created to provide assistance to county flood control districts in investigating flooding problems and developing plans to control such problems. Another substantive policy is the Flood Control Loan Program, which was established to enable county flood control districts to proceed with timely implementation of flood control projects authorized for funding under the Alternative Flood Control Assistance Program.

### **Mitigation Challenges**

Funding has been identified as one of the primary barriers limiting the implementation of mitigation measures throughout the state. In 2004, funding for PDM was \$150 million and has dropped to a low point of approximately \$25 million at one point in time. The inconsistent funding has affected mitigation statewide. Additionally, we have not been successful in obtaining FMA funding in the past. Federally declared disasters are not commonplace in Arizona, making HMGP funding rare for the state.

Grant funding sources are not the only challenge to implementing mitigation measures. Local jurisdictions, counties, and tribal governments experience difficulty allocating funds for the 25% match required by federal grants. These financial constraints have prevented many from applying for mitigation funding. Arizona continues to work on identifying new funding sources and implementing the most cost effective and beneficial mitigation measures in order to overcome existing barriers to mitigation implementation.

## SECTION 6: LOCAL MITIGATION CAPABILITIES

### LOCAL MITIGATION POLICIES, PROGRAMS, AND CAPABILITIES

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Just as disasters are local, mitigation is performed at the local level. The state supports local and tribal governments with mitigation planning through training, technical assistance, and funding. This ensures that the community is aware of hazard data, planning resources, and state priorities for mitigation. To date, DEMA has, or is currently, assisting county and tribal emergency management agencies in updating their hazard mitigation plans. To support effectively, the state must understand the local and tribal capabilities as they pertain to implementing mitigation measures. Likewise, consideration of local and tribal mitigation strategies and capabilities information may influence the state's risk assessment and mitigation priorities.

Each county has developed specific requirements and capabilities based on their individual needs and circumstances. Despite the many challenges local, county, and tribal jurisdictions face, they have consistently demonstrated resistance to hazards as demonstrated by the low frequency of events being escalated to the state level. Local, county, and tribal jurisdictions utilize policies, programs, and capabilities in order to maintain capacity and best serve the community.

The following are examples of local capabilities at the county level. Information on city and town jurisdiction capabilities will be located in their respective county hazard mitigation plans. Additionally, the data presented in the following subsections were obtained from the counties through their most recently approved, or pending approval, hazard mitigation plans.

#### **Building Codes**

Many jurisdictions adopt the Uniform and International Building Codes with amendments in order to mitigate the impacts of various hazards. Building codes ensure the design and construction of buildings meet optimal safety requirements and standards.

The adoption of building codes is not enforced by the state. Counties and local jurisdictions are given autonomy in the development and implementation of building codes based on their needs and concerns. Of the 15 counties in Arizona, 6% have adopted the 2015 IBC, 60% have adopted the 2012 IBC, 26% have adopted the 2006 IBC, and 6% have not adopted any version of the IBC.

#### **Comprehensive Planning**

Comprehensive planning is a state requirement and is a foundation for various planning documents and ordinances that provide for the future growth and improvement of their respective jurisdiction. A comprehensive plan is a document that guides the future actions of a community by presenting a vision for the future with long-term goals and objectives for all activities that affect the local government. Comprehensive planning provides for the health, safety, and general welfare of citizens through orderly development and designated land use.

Of the 15 counties, 53% have adopted updated comprehensive plans since 2015, 20% have adopted updated comprehensive plans between 2010 and 2014, and 27% have not recently adopted comprehensive plans with their last adoption occurring prior to 2010.

### **Emergency Operations Plans (EOP)**

Under ARS 26-308, state emergency plans shall be in effect within all subdivisions and jurisdictions within the state, and the governing bodies of each subdivision and jurisdiction may develop additional emergency plans in support of state emergency plans. This includes all response and recovery efforts outlined in the State Emergency Response and Recovery Plan (SERRP).

Of the 15 counties, 27% have adopted an updated EOP since 2015, 20% have adopted an updated EOP between 2010 and 2014, 40% have not recently adopted an updated EOP with their last adopting occurring prior to 2010, and 13% have not adopted, or made public, their EOP.

### **Floodplain Management**

State legislature delegates the responsibility of adopting regulations to each county flood control district and their floodplain manager. The floodplain manager is responsible for corrective and preventative measures that reduce flood damage. These measures include zoning, subdivisions, and special purpose floodplain ordinances. Floodplain management further includes regulations that promote public health and safety, and minimize losses from flooding. Additionally, floodplain management considerations may include zoning restrictions and regulations for areas that are known to house repetitive loss and severe repetitive loss properties.

Of the 15 counties, 40% have adopted updated floodplain ordinances since 2015, 40% have adopted updated flooding ordinances between 2010 and 2014, and 20% have not recently adopted updated flooding ordinances, with their last adoption occurring prior to 2010.

### **Subdivision**

The state requires counties to identify land that is to be subdivided or proposed to be for the purpose of sale or lease, whether immediate or future, into six or more lots or parcels. Subdivisions provide for the orderly growth and development that secures adequate provisions for water supply, drainage, storm water detention, sanitary sewerage, health and safety requirements, and protection from floods. This ensures the identification of adequate sites for schools, recreational areas, and public facilities.

Of the 15 counties, 27% have adopted updated subdivision ordinances since 2015, 6% have adopted updated subdivision ordinances between 2010 and 2014, 47% have not recently adopted updated flooding ordinances with their last adoption occurring prior to 2010, and 20% have no public history of adopting any subdivision ordinances.

### **Zoning**

The state requires counties to adopt ordinances identifying zones for a particular purpose or residential area. Zoning practices divide the county into land use zones as delineated on the official zoning maps, and sets regulations for the promotion of the health, safety, morals, convenience, and welfare of citizens. Of the 15 counties, 47% have adopted updated zoning ordinances since 2015, 6% have adopted updated zoning ordinances between 2010 and 2014, and 47% have not recently adopted updated zoning ordinances, with their last adoption occurring prior to 2010.



**Mitigation Challenges**

Many of the counties throughout the state do not have the most current plans and programs to guide their communities towards a resilient future. This is mainly due to the fact that the majority of counties are rural with flat or negative population growth. This trend tends to limit the availability and appropriation of staff and resources toward growth management, mitigation activities, and overall preparedness. However, the counties with the highest population densities and growth have updated or current plans, and have adopted more recent zoning and building codes.

## LOCAL & TRIBAL PLANNING COORDINATION, PLAN INTEGRATION, AND FUNDING PRIORITIES

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### Local and Tribal Planning Coordination

DEMA has and continues to take a proactive approach to assisting our local jurisdictions and tribal governments in the development of their hazard mitigation plans and plan updates. From the beginning of the DMA2K requirement, DEMA has applied for and been awarded FEMA grant funding on behalf of the local and tribal planning participants, to hire a contractor to assist in developing and updating their plans. In these instances, DEMA has managed contractor performance to ensure effective plans were being developed and the best interest of jurisdictions and tribes were a priority. There has also been technical assistance provided directly by DEMA to jurisdictions and tribes who obtained their own planning funds or developing their plans without outside resources. In these instances, DEMA facilitates the planning process according to what the jurisdiction or tribe wishes to accomplish. A priority in our planning assistance is the focus on developing a plan that reflects the unique characteristics of the participating jurisdiction or tribe. We realize each community and tribe is different in geography, hazards, beliefs, resources, leadership, and values.

DEMA prioritizes coordination and assistance primarily according to plan expiration dates. However, should the issue arise, there may be consideration given based on new hazard development and/or major changes needing to be incorporated into local and tribal plans.

Since 2016, DEMA has discontinued obtaining grant funding to assist in developing local and tribal hazard mitigation plans. We now offer planning assistance, guidance, and training opportunities or assist in obtaining grant funding as needed.

To provide further planning assistance, DEMA routinely delivers FEMA course *G393: Mitigation for Emergency Managers* at various locations throughout the state. The class has resulted in an increased awareness of planning processes and leaves the students better prepared to participate in their respective mitigation planning process.

In addition to providing technical assistance, DEMA reviews local and tribal hazard mitigation plans. All local jurisdictions must and tribal jurisdictions may submit their plans to DEMA for both initial review and subsequent forwarding to FEMA for final review and approval. Local and tribal hazard mitigation plan reviews are performed according to and using FEMA's most current review tools.

In the event a plan does not adequately meet the requirements, DEMA offers assistance to revise the plan to ensure it is effective and will have a successful review by FEMA.

Part of the local and tribal planning coordination is assistance conducting plan evaluations during their plan's valid period.

The annual review process can help remove barriers to implementing the mitigation plan by continuous evaluation of the progress on the activities outlined in their mitigation strategy. Mitigation plans are intended to be usable living documents that are continually monitored. The results of the reviews, whether annual or following a disaster, have the potential to inform decisions regarding implementation as well as making the update process more efficient.

### **Local Plan Integration**

It is the state's goal to ensure that the local and state mitigation plans are properly aligned and reflect the priorities in this Plan. We continue to integrate and link the state hazard mitigation plan with that of the local jurisdictions as well as the tribes when asked for assistance.

To ensure future success in this area, we intend to:

- Link pertinent information to this Plan as new information is available or new plans are approved;
- Encourage local jurisdictions and counties to develop effective multi-jurisdictional mitigation plan updates by;
  - Notification/education of the benefits through outreach and education activities.
  - Dissemination of the latest requirements, guidance publications and lessons learned by DEMA and offer plan coordination and technical assistance to local jurisdictions and tribal governments.
  - Offering the delivery of FEMA course *G393: Mitigation for Emergency Managers*;
- Distribute the State Plan to all county emergency managers and make available to all local jurisdictions and the public by posting on DEMA website following approval from FEMA; and
- Encourage the use of this Plan's framework to allow smooth integration with the State Plan.

### **Prioritizing Local Funding**

DEMA administers FEMA's Hazard Mitigation Assistance (HMA) grant program for the State of Arizona. The grant program is delivered to state agencies and local jurisdictions, while tribes in Arizona apply directly to FEMA. The HMA program consists of three grant programs: Pre-Disaster Mitigation (PDM), Flood Mitigation Assistance (FMA), and Hazard Mitigation Grant Program (HMGP). The prioritization factors used for PDM and FMA may include:

- Direct impact on life safety
- Projects that provide the most benefits to the community
- Mitigation of repetitive loss (RL) or severe repetitive loss (SRL) structures/properties
- Benefit to impoverished communities
- Non-planning activity projects
- Cost effectiveness

For HMGP, the additional funding factor is the structure/property being located in the affected area(s).

Projects undergo a thorough and unbiased review conducted by a panel of participants who are selected based on knowledge and experience, and are often members of other state agencies or local jurisdictions.

## **SECTION 7: PLAN MAINTENANCE AND IMPLEMENTATION**

### **MONITORING AND EVALUATION**

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Regulation requires a plan maintenance process that establishes a method and schedule for monitoring, evaluating, and updating the plan, a system for monitoring implementation of mitigation actions and project closeouts, and a system for reviewing progress on achieving goals identified in the mitigation strategy. These maintenance components are discussed in this section.

The DEMA Planning Branch is responsible for developing and maintaining the Plan and additional participants in plan maintenance may include the members of the Planning Team.

The Plan will be reviewed annually to reflect significant policy changes that took place during the preceding year and to report on progress made and other findings. The annual review will take place at the end of each calendar year. The DEMA Planning Branch staff and other participants will perform this review as follows:

- Examine progress or changes in hazards and emergency/disaster occurrences.
- Examine progress on mitigation measures in the statewide mitigation strategy.
- Identify challenges in implementing mitigation measures.
- Recommend how to solve such challenges, possibly by increasing involvement of state agencies and the private sector.
- Review, revise, and update the state capability assessment and the statewide mitigation strategy to reflect changes in policies, priorities, programs, and funding.
- Review hazard profiles for which significant new information is available that could change the risk level or area of impact.

The review findings will be documented and distributed to the Planning Team and others involved in the review. The documentation will be maintained in the Planning Branch.

After an emergency or disaster, the Plan will be reviewed. Planning Branch staff will coordinate the review with the Planning Team, subject matter experts, and other stakeholders. Observations and data related to the disaster will be shared to identify specific mitigation needs related to the disaster-affected area. This information will help to inform how the Plan is affected and where adjustments may be warranted. The post-disaster review may replace an annual review in any year that a major disaster occurs, depending on the disaster event's severity and time of year.

### **UPDATING THE PLAN**

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The Planning Branch staff will facilitate the review and update of the Plan every five years. The following will be encouraged and invited to participate; previous Planning Team members, subject matter experts, and other stakeholders. The review and update process will begin approximately 1 year before plan expiration. This process will incorporate all revisions and findings resulting from annual and post-disaster reviews, particularly new hazard identification and risk assessment information. The significant areas of focus during the update will be as follows:



- Revising the risk assessment to remain current and accurate. This may include adding or omitting hazards, incorporating new information on risk and vulnerability, and integrating information from local mitigation plans.
- Examine and document the progress on, and determine the effectiveness of, the mitigation actions outlined in the mitigation strategy.
- Examine the effectiveness of funded local mitigation projects and determine how successful the implementation was and what challenges were present.
- Examine the overall implementation of the Plan, identify challenges and develop recommendations to overcome them.
- Following review and revision of the Plan, analyze the maintenance process and the project monitoring process, and make changes to improve these processes as needed.

The overall update process will be conducted using a team approach and decisions will be made by consensus to ensure the knowledge and experience of the team is used to develop the most accurate and effective Plan possible.

The Plan will be sent to FEMA for review and upon an ‘approvable pending adoption’ determination will be promulgated by the Director of DEMA, Division of Emergency Management. The most current Plan will always be available on our website.

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## **MONITORING, IMPLEMENTATION, AND REVIEWING PROGRESS**

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### **Monitoring Projects**

#### **FEMA Funded**

The SHMO is responsible for monitoring and evaluating the progress, and completion, of FEMA funded mitigation projects. Monitoring activities ultimately begins with a meeting between the State Mitigation Office (SMO) and the sub-grantee to ensure all parties are aware of the requirements set forth by federal regulations and the appropriate grant program. The amount of monitoring conducted varies depending on the complexities of the project and the expertise/experience of the sub-grantees. Recognizing “danger signals” can indicate the amount of monitoring necessary for a project. “Danger signals” can present as failing to file quarterly reports timely or showing a lack of progress, expenditures that do not match the percentage of project completion, a change in project manager, etc.

The Mitigation Coordinator conducts project monitoring through ongoing communication, random site visits and inspections, and by analyzing quarterly reports to verify progress. Upon completion of a project, the Coordinator will schedule a final inspection with the sub-applicant. The final inspection includes a final site inspection and a review of the financial documentation in preparation for audit by the state.

Project timelines and schedules for FEMA funded projects will vary, and are dependent on the respective grant program guidelines.

DEMA will utilize any and/or all of the above methods, as determined by the SMO.

### **Non-FEMA Funded**

The Planning Coordinator, in coordination with the designated lead agencies/stakeholders, will conduct annual reviews of the Plan to evaluate the progress of the mitigation strategy and measures. Mitigation strategy annual reviews will be documented, and should include information regarding mitigation action priority levels, funding source(s), resources, project start/completion dates, and progress of specific activities. Additionally, annual reviews will be utilized to analyze the applicability of the existing mitigation measures, and address challenges hindering implementation.

### **Monitoring Projects in this Plan**

The mitigation measures in this Plan will be evaluated as outlined in the Plan Maintenance section of this Plan. A documentation of the measures will be updated as monitoring and reviews occurs and when additional progress is reported or other communication/correspondence is made regarding the measures. The database will include but is not limited to the following information:

- Measure
- Priority level
- Lead and participating agencies
- Funding or resource source(s)
- Project start/complete dates
- Correspondence/communication
- Progress indicated by specific activities

Mitigation measures presented in this Plan were presumed to be actionable and at least started if not completed by the expiration of this Plan. The designated measure's "lead" is responsible for securing the necessary funding and other resources, coordinating the project's implementation, monitoring progress, and maintaining detailed records of related activities.

### **Accountability of Funds**

DEMA, serving as grantee, has primary responsibility for project management and accountability of funds as indicated in 2 CFR, Part 200. DEMA is responsible for ensuring that sub-grantees meet all program and administrative requirements.

The State Hazard Mitigation Officer (SHMO), is responsible for monitoring mitigation projects in accordance with 2 CFR, Part 200. The process to track and monitor mitigation activities has not changed.

### **Sub-Grantee Record Keeping Requirements**

Federal regulations (44 CFR, Parts 13.20 and 206.205) require each Sub-grantee to maintain a system that accounts for FEMA funds on a project-by-project basis. The system must disclose the financial results for all current those activities accurately and completely. It must identify funds received and disbursed, as well as reference source documentation.

Federal regulations (OMB Circular A-87 and 44 CFR, Part 13.20) require that costs claimed under federal programs must be adequately supported by source documentation such as cancelled checks, invoices, payroll, time and attendance records, contracts, etc. Each Sub-grantee must

maintain full documentation in order to receive payment. The Sub-grantee will be required to document all expenditures and implement monitoring procedures for review by the SMO. Quarterly reports are to be submitted to DEMA on the status of completion dates, any changes in the scope of work, and project costs to date. The SMO will require submission of documentation before any reimbursement is made.

## **Closeout Procedures**

### **Subgrant Closeout**

Prior to close out of a subgrant, Mitigation Office staff will inspect all projects for completion and compliance. If documentation, inspections, and other reviews reveal issues in performance of work or the documentation, staff will work with the subgrantee's applicant agent to correct the deficiencies before closeout. Items required to be submitted with the subgrant closeout request are:

- Final invoice with supporting documentation
- Final quarterly report
- Letter requesting final reimbursement
- Project photographs
- List of planned maintenance

Elevation projects will also require:

- Before and after photos
- Copies of pre- and post-construction elevation certificates
- Signed, recorded deed notices

Acquisition projects will also require:

- List of all properties acquired including address, parcel number, longitude and latitude
- Copies of signed recorded deeds

The SHMO will submit the final closeout request to FEMA including the documents listed above.

The SHMO will submit a final project closure package to terminate the FEMA-State Agreement when all subgrants have been closed. The package will include:

- A list of all projects with the eligible expenditures
- Certification that all funds have been expended in accordance with the FEMA-State Agreement utilizing the SF 425

When all payment of these funds has been made, the SHMO determines the final eligible administrative allowance and requests reimbursement from FEMA. Upon receipt of this allowance, the SHMO notifies the Regional Administrator in writing that no further claims for the disaster will be made and that all program activity has been closed.

## **ANNEX A: PREVIOUS MITIGATION STRATEGY ASSESSMENT**



### 2013 State Hazard Mitigation Plan: Mitigation Action Review

New or Existing	Hazard Mitigated	Mitigation Measure Description (In order of High, Medium, Low Priority) Status (*represents the mitigation measures 2018 update)	Lead Agency	Est Cost	Est Comp	Pot Funding Source
N	Terrorism	Administer “Partners for Arizona’s Safety & Security” (PASS) by providing terrorism subject bulletins to public and private partners. PASS is a program based on terrorism awareness with such partners as USDHS, FBI, AZDOHS, DEMA , and AZDHS acting as the steering committee. *This did not occur and this is not a feasible mitigation measure.	DEMA	N/A	Ongoing	N/A
<b>Delete</b>		Bulletins are disseminated on an as available and as needed basis.				
N	Terrorism	Perform duties as liaison to the Arizona Counter Terrorism Information Center (ACTIC) and coordinate the dissemination of terrorism related information to appropriate parties as needed.	DEMA	N/A	Ongoing	N/A
<b>Delete</b>		Activity is already ongoing and will continue as described. *This is not a mitigation measure but rather someone’s regular job responsibilities.				
E	Flood	Assist local jurisdictions in acquiring, or otherwise mitigating property located in the 100-year floodplain, beginning with repetitive loss properties.	ADWR, DEMA, Flood Cont Districts	N/A	Annually	N/A
<b>In progress</b>		Some local jurisdictions have acquired homes in the floodplain that was converted to open space. ADWR investigates NFIP compliance of repetitive loss properties and discusses mitigation opportunities with local jurisdictions. DEMA continues to work with local jurisdictions and solicit grant applications in order to acquire eligible repetitive loss properties. *ADWR continues to investigate NFIP compliance for repetitive loss properties. The DEMA State Hazard Mitigation Officer conducts outreach and presentations to counties at the beginning of each calendar year to educate and encourage the submittal of FEMA HMA grant application.				
E	Flood	Investigate areas with the potential for debris flows and flooding in the post-fire environment & identify high-risk areas for incorporation into mitigation plans and to target areas for mitigation activities.	AZGS	\$200k	Ongoing multi-year project	FEMA 5% Initiative Study
<b>In Progress</b>		Recent mapping in Gila County. Released report evaluating debris flow potential in the post-wildfire environment in Gila County. Research into post-fire debris flows is ongoing. Funds for dedicated studies are lacking. AZGS recently published the Southwest Wildfire Hydrology & Hazard Workshop Proceedings, summarizing the state of knowledge of post-wildfire debris flows in the Southwest. *A recently completed study for Coconino County identified areas potentially at risk from post-wildfire debris flows. Two of the identified areas were then studied in detail to estimate risks and to identify potential mitigation options. It was funded by FEMA’s RiskMap program. Other research into post-fire debris flows is ongoing but funds for dedicated studies are lacking.				
N	HazMat	Manage an online database for Hazardous Materials and Extremely Hazardous Chemicals in which facilities in Arizona upload Tier II information for viewing by Fire Depts. and Local Emergency Planning Committees for response and planning activities to mitigate against HazMat incidents.	AZSERC	\$20k/year	Annual Ongoing	DEMA
<b>In progress</b>		By the end of this year’s reporting cycle (March 1, 2013) 4,100+ Arizona facilities have entered their Tier II information into the database. *4,100+ facilities still enter information into the database. Database is maintained by ADEQ and updated by facilities on an annual basis.				
N	HazMat	Distribute funds to the Local Emergency Planning Committees (LEPCs) to support HazMat planning, training and equipment. The LEPCs have Response Plans in the event of a HazMat incident. The HazMat training is for first responders and the equipment enhances the County HazMat Teams.	AZSERC			

### 2013 State Hazard Mitigation Plan: Mitigation Action Review

New or Existing	Hazard Mitigated	Mitigation Measure Description (In order of High, Medium, Low Priority) Status (*represents the mitigation measures 2018 update)	Lead Agency	Est Cost	Est Comp	Pot Funding Source
<b>In progress</b>		Already being implemented. *Grant fund letters have been sent to LEPC. HMEP awards are being processed.				
E	Wildfire	Continue to complete wildland fuels reduction projects as appropriate and renew/revise agreements as necessary. Necessary for those living in or owning property in the WUI or Communities At Risk to manage the fuels on their properties to reduce their risk from wildland fires. It is also equally important that agencies reduce the fuel loading on public lands in order to further reduce the risk of destructive wildfires.	State Forestry, DOC	N/A	Ongoing	N/A
<b>In Progress</b>		Actively prioritizing projects as federal grant funding is awarded. *No change as this is continuous operations				
E	Multi	Add requirements to building codes for fire resistive materials for new construction and additions to existing construction. One element of Statewide Strategy for Restoring Arizona's Forests: encourage community leaders to take steps to mitigate against wildfire by encouraging local implementation of WUI codes.	State Forestry	N/A	Ongoing	N/A
<b>In Progress</b>		Governor's Forest Health Council work plan includes outreach to communities regarding WUI codes and Firewise practices. Provides public forums for community leaders; six communities have adopted codes. *No new communities have adopted codes but implementation and advocacy efforts continue				
N	Earthquake, Fissure, Flood, Wildfire	Enhance hazards viewer which contains hazard specific information to increase public awareness for citizens and local emergency managers.	AZGS, DEMA	\$100K (initial phase)	2014	FEMA
<b>Completed</b>		AZGS in coordination with DEMA are in the process of developing this hazards viewer which not only contain four different hazard layers, but will also incorporate mitigation measures for each hazard and be linked to AzEIN for additional information. The project is expected to expand to include additional wildfire information if funding becomes available from Arizona Forestry. *The hazards viewer now contains data for five hazards (earthquake, fissures, landslides, flood, and fire risk). Updating GIS data is needed.				
E	Dam	Coordinate with county and community emergency management and floodplain management officials and provide information regarding the status, potential hazards and risks associated with deficient dams so that those communities can make better informed decisions regarding planning and development.	ADWR	N/A	Annually	N/A
<b>In progress</b>		ADWR maintains a listing of deficient dams and requires updated Emergency Action Plans from all owners of high and significant hazard potential dams. Specifically, ADWR and the dam owners have made local entities potentially affected by Magma Dam in Pinal County (repairs underway and expected to be completed in 2013), Fredonia Dam in Coconino County, Powerline Dam in Pinal County (repairs underway and expected to be completed in 2013), and Cook Reservoir Dam in Graham County are each made aware of potentially elevated risks due to deficiencies. *ADWR continues to require updated EAPs for all high and significant hazard potential dams. ADWR alters the list of deficient dams as needed.				
E	Wildfire	Maintain up to date list of Arizona Communities at Risk (of wildfire) and share with agencies or individuals who can use the information to benefit their respective communities. This will provide a benefit to State Forestry and communities in identifying priority areas for wildfire mitigation	State Forestry	N/A	Ongoing	N/A

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New or Existing	Hazard Mitigated	Mitigation Measure Description (In order of High, Medium, Low Priority) Status (*represents the mitigation measures 2018 update)	Lead Agency	Est Cost	Est Comp	Pot Funding Source
		work and is required by the National Fire Plan as well.				
<b>Completed</b>		This information has been updated in conjunction with GIS mapping updates and routine Forestry Division district interaction with communities and fire districts and the information is now posted on our agency website. *The mitigation action is completed and publicly available. Data will be updated on an as needed basis.				
E	Dam	Identify adequate funding sources of the dam repair program, which is designed to assist the state and the owners in the protection of life and property. Report to the Director of ADWR.	ADWR	N/A	Annually	N/A
<b>In progress</b>		ADWR manages Dam Repair Funds and routinely makes grants to owners of unsafe dams. Two grants provided in 2009. Funding was provided and work has been completed on the engineering design and plans for rehabilitation of Millet Swale Dam in Navajo County and for removal of Cook Reservoir Dam in Graham County. Both projects currently seek funding for construction costs. Due to the economic recession and legislative sweeps of the Dam Repair Fund, no additional dam projects have been funded since 2009. Recent increases to ADWR's Dam Safety permit and inspection fees may make funding for additional projects in the near future. *ADWR used a grant from DEMA to hire a consultant to develop and Emergency Action Plan for Fredonia FRS. In addition, ADWR is coordinating with two dam owners to partner on projects to address safety deficiencies at their dams.				
E	Flood	Continue to encourage homeowners and renters who live in areas that are flood prone to acquire flood insurance through the NFIP.	ADWR, Flood Cont Districts	N/A	Ongoing	N/A
<b>In progress &amp; Revise</b>		ADWR promotes flood safety and awareness through the Community Assistance, National Flood Insurance and Risk MAP Programs. Staff created two outreach brochures for distribution to communities and residents: "Manufactured Homes, Recreational Vehicles, Park Trailers and Floodplains" and Wildfire and Flood Risks". *ADWR promotes community compliance, training and outreach regarding the National Flood Insurance Program. Staff conducted training workshops, Community Assistance Visits, Community Assistance Contacts, and provided general technical assistance to incorporated and unincorporated areas throughout Arizona.				
E	Wildfire	Encourage cities, communities and other municipalities to specify landscaping requirements based upon Firewise principles. Necessary for those living in or owning property in the WUI or Communities at Risk to manage the fuels on their properties to reduce their risk from wildland fires.	State Forestry	N/A	Ongoing	N/A
<b>In progress</b>		Forestry Division staff conduct outreach, especially the District Forestry staff in our three districts -Tucson, So Arizona, Phoenix District in Central AZ, Flagstaff District in No Arizona. This outreach has resulted in Arizona holding one of the highest community certification rates in the nation at 45. *Outreach is now conducted in five districts - Northern AZ in Flagstaff, Northeastern AZ in Pinetop, Southeastern AZ in Tucson, Central AZ in Phoenix, and Northwestern AZ in Chino Valley.				
E	Wildfire	Maintain GIS wildfire incident database. Share data with local jurisdictions and others that may benefit from it by using it to identifying areas at risk and prioritize project areas based on present fuels, threat to the public and natural resources and to track the location and progress of ongoing projects.	State Forestry	N/A	Ongoing	N/A
<b>In Progress</b>		With database complete, the information is collected and updated on a yearly basis. *Information continues to be gathered as the climate, and physical and built environment continue to change and impact/alter the hazard areas.				

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E	Severe Weather	Add information on the dangers of severe weather to the State Climatology website and continue weather presentations to K-12 students and community groups. The state Climatology Office engages in both, applied research and outreach, making presentations to both k-12 and community groups on various weather and climate topics. The webpage also provides weather and climate information to the general public. As internet accessibility expands, websites are becoming a primary source of information. Providing severe weather hazard information on the State Climate website will help educate the public and potentially reduce injuries or damage due to severe weather. Severe weather presentations are always favorites with K-12 students and community groups and they are very useful for correcting misinformation about hazards.	State Climate Office	N/A	Initial phase done, now ongoing.	N/A
<b>Completed</b>		Educational visits to K-12 and community groups continue. Currently in planning stage to add severe weather preparedness to the website, in accordance w/ the NWS guidelines. *Severe weather preparedness has been added to the website as part of the Severe Weather page. This includes information on all weather hazards. Education to K-12 and community groups occur 1-2 times per month but this action considered complete now that the information is publicly available.				
E	Wildfire	Distribute wildfire mitigation information to those applying for building permits and those communities seeking Firewise Communities recognition. It has been repeatedly demonstrated that education is a key component in convincing the public to endorse and adopt wildland prevention and Firewise principles and activities.	State Forestry	N/A	Ongoing	N/A
<b>In progress</b>		The growing list of Firewise Communities in Arizona at 45 is a significant indicator of mitigation work accomplished to prevent or reduce wildfire risk. *The number of Firewise Communities has grown to 87.				
E	Flood	Continue monitoring and coordinating with State NFIP Coordinator & FEMA to identify properties that meet Repetitive Loss or Severe Repetitive Loss criteria.	DEMA Mit Office	N/A	Ongoing	N/A
<b>Delete</b>		DEMA receives listings of RL/SRL properties and will continue to notify the appropriate County Emergency Managers to make them aware of these properties. DEMA will also continue to make them aware of funding sources to mitigate these properties. *This is not a DEMA responsibility as ADWR works with communities with these properties.				
E	All	Continue to provide local jurisdictions with technical assistance in developing their future hazard mitigation plan updates.	DEMA Mit Office	N/A	Ongoing	N/A
<b>Delete</b>		DEMA has provided planning assistance to all 15 counties on their original plans and first updates. The County plans are all now multi-jurisdictional, so in assisting them, we are also assisting their respective incorporated jurisdictions. We have also offered assistance to all tribes and actually assistance approximately 15 of them in their plan development. We intend to continue the same level of assistance in the development of the second plan updates. *This is part of our daily responsibilities at the state level and is not considered a mitigation action.				
E	Floods	Conduct surficial geologic mapping to evaluate piedmont areas that may be prone flooding.	AZGS	N/A	2008-2011	N/A
<b>In progress</b>		Several reports and maps published. Released numerous geologic quadrangle maps showing extent of young deposits, interpretations of flood hazards. As part of the StateMap program, we continue to map and evaluate flood hazards on piedmonts. The resulting maps and reports, including several Contributed				

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		Reports are available at no charge at the AZGS online document repository (repository.azgs.az). *Evaluating flood hazards on piedmonts continues				
E	All	Continue to distribute mitigation brochures to the public.	DEMA Mit Office		Ongoing	
	Delete	Brochures have been distributed through meetings. Workshops, conference and Individual Assistance Service Centers set up in areas affected by disasters such as the Yarnell Hill Fire. We have also made the brochure available in ready to print and printer ready artwork formats via DEMA 's website. Our brochures include "Wildfire and Flood Risks", "Mitigation for Citizens", and "Arizona Shake – Seismic Hazard Awareness". *DEMA no longer has mitigation brochures for distribution and the wildfire and earthquake brochures will not be replenished.				
E	Fissure	Conduct earth fissure planning map briefings for state and local agencies whose responsibilities are affected by fissures.	AZGS	\$25k	Ongoing	FEMA HMGP
	In progress	Briefings for agencies associated with initial releases of earth fissure maps; continued interaction with local and state agencies. AZGS continues to communicate with local and state authorities about earth fissures. Civil authorities are notified upon the release of new earth fissure maps. At the onset of each monsoon season, we issue a reminder to county authorities regarding earth fissures and request information on any new or ongoing development. *The previous process remains in place and the effort is ongoing				
N	HazMat	Provide consultative services, conduct and participate in workshops and coordinate development and review of plans and programs for 15 Local Emergency Planning Committees (LEPC).	ADEQ	\$20k/year	Annual Ongoing	DEMA
	In progress	Already in progress. *Program is in the process of being improved. At this time ADEQ employees are attending meetings and providing guidance.				
E	Multi	Increase public awareness of geologic hazards - earth fissures, landslides, debris flows and flash floods via workshops, online resources, media and other outreach avenues through AZGS Geologic Extension Service.	AZGS	\$80k annually	Ongoing	FEMA HMGP
	In progress	Fissure and earthquake outreach programs are active. AZGS continues to develop print and web outreach products describing geologic hazards in Arizona. In 2012, and in partnership with DEMA , we hosted the Great Arizona ShakeOut with 62,500 Arizonans participating. Our Arizona Shakes Earthquake Outreach program is our most successful hazard awareness program due to annual funding from the National Earthquake Hazard Reduction Program. Funding for other geologic hazard awareness programs are wholly lacking. *We expanded outreach by partnering with DEMA to promote the Great Arizona ShakeOut program to municipal, county and tribal emergency management offices, health authorities, volunteer organizations, K-12 education community and the public. Funding for other outreach initiatives continues to be an issue.				
E	Earthquake	Obtain seismic stations and monitor and analyze activity to re-assess the seismic hazard (which is underestimated) for the state and identify areas that are particularly vulnerable. Release the information via public outreach to allow jurisdictions to determine appropriate mitigation measures and establish appropriate seismic building codes.	AZGS	\$50k	2008-2011	N/A
	Completed	Collaborative monitoring effort with ASU, NAU and UofA. Acquired and are operating 8 modern seismometers arrayed across the state; conducting research in cooperation with state universities to use data in updated seismic hazard assessments. AZGS continues to operate the Arizona Broadband Seismic Network. Vandalism has reduced the number of operational seismometers from 8 to 7. We continue to search for funding sources to assure sustainability of the network. *The Arizona Broadband Seismic Network now has 13 modern seismometers across the state. Monitoring seismic activity is continuous and information will be				



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New or Existing	Hazard Mitigated	Mitigation Measure Description (In order of High, Medium, Low Priority) Status (*represents the mitigation measures 2018 update)	Lead Agency	Est Cost	Est Comp	Pot Funding Source
		distributed as needed.				
E	All	Develop and maintain a database of past/current funded mitigation projects to track progress and publish project/success stories.	DEMA Mit Office	N/A	2008 and & ongoing	N/A
<b>Delete</b>		Database has been populated with grant award information and work continues on documenting project details. This database will help ensure historical mitigation project information is not lost. *This is not a mitigation measure.				
E	Flood	Encourage communities to begin or continue participation in the Community Rating System (CRS) program to ensure credit for various activities that assist property owners in receiving reduced insurance premiums and to reduce flood damages.	ADWR	N/A	Ongoing	N/A
<b>In progress</b>		ADWR discusses the benefits of the CRS program and encourages participation during Community Assistance Program meetings with NFIP communities. Currently, 25 communities participate in the CRS program and two more are considering joining. *26 communities have earned enough CRS credits receive discounted flood insurance premiums for residents.				
E	Earthquake	Distribute earthquake hazard information via hard copy and internet (including posters and presentations, monitoring and activity updates, etc).	AZGS	\$50k/yr	2010 & ongoing	FEMA NERHP
<b>In progress</b>		Working on web and print materials. AZGS continues to aggressively pursue an earthquake hazard outreach program. Recent outreach publications include: earthquake preparedness brochures, Arizona is Earthquake Country Down-to-Earth text, and videos exploring Quaternary faults in Arizona. With DEMA we hosted the Great Arizona ShakeOut in October 2012. The second Great Arizona ShakeOut is scheduled for October 2013; as of May 26, 2013, nearly 10,000 Arizonans are enrolled in the program. NEHRP funding in 2014 is at risk. The loss of funding will adversely impact AZGS efforts to alert the Arizona public to earthquake hazards. *In 2015, enrollment was ~124,000. In 2016, enrollment dropped to 65,500 in 2017. NEHRP funding was pulled for several years critically impact our earthquake preparedness program. We are likely to receive ~\$31,000 for FY-2018, with AZGS dollar-for-dollar match, we'll invest more than \$62,000 in earthquake outreach in 2017-2018.				
E	Landslide	Map and identify active and paleolandslides in order to identify areas susceptible to landslide occurrence.	AZGS	\$200k	Ongoing	FEMA HMGP
<b>Completed</b>		Some action along Beeline Hwy near Payson. Several landslides identified as part of StateMap mapping program. Where encountered as part of AZGS's StateMap program, paleolandslide masses are mapped. Funding for systematic statewide study of landslide hazards has not been procured. *Created a new landslides database of previously mapped landslides to establish a baseline of known landslides within the state. The database was added to the natural hazards viewer. A final report and a landslide hazard profile were completed. Numerous landslides not previously identified were added to the database. None of these landslides have been field mapped or verified; recency of landslide activity generally not known; funding will be needed to improve mapping and provide more information about individual				

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New or Existing	Hazard Mitigated	Mitigation Measure Description (In order of High, Medium, Low Priority) Status (*represents the mitigation measures 2018 update)	Lead Agency	Est Cost	Est Comp	Pot Funding Source
		landslide areas.				
E	Wildfire	Ensure Arizona Firewise Communities program and fire prevention information is distributed statewide. It has been repeatedly demonstrated that education is a key component in convincing the public to endorse and adopt wildland fire prevention and Firewise principles and activities.	State Forestry	N/A	Ongoing	N/A
<b>In progress</b>		All three field districts for State Forestry Divisions meet with Fire Chiefs in their respective districts monthly, quarterly and annual meetings, conference and training sessions and advocate wildland urban interface and Firewise models. *There are now 5 districts under DFFM and outreach on a monthly, quarterly, and annual continues in order to the adoption of Firewise principles.				
E	Earthquake	Investigate quaternary (young) faults to estimate the time since the most recent event, average recurrence intervals or slip rates and to estimate paleoearthquake magnitudes. This information can be used for seismic hazard assessments, including probabilistic earthquake hazard maps, which in turn can be used to plan mitigation projects.	AZGS	\$50k per fault	Ongoing	USGS StateMap Prog & ADOT
<b>In progress</b>		Some mapping complete. Investigated one quaternary fault zone in western Arizona in 2007-08 as part of mapping project for ADOT; discovered on quaternary fault zone north of Prescott and team is mapping two other as part of StateMap program. AZGS monitors seismic activity in Arizona with the Arizona Broadband Seismic Network. Where encountered as part of AZGS's StateMap program, faults are mapped and characterized. A new Quaternary fault map is in a preliminary state of construction. Funding for detailed characterization of Quaternary faults has not been procured. *Mapping and revising previously documented faults continues through the StateMap program. Funding for detailed characterization of Quaternary faults has not been procured.				
E	Landslide	Coordinate research priorities to develop a predictive understanding of landslide processes & triggering mechanisms.	AZGS	\$200k	2008 & ongoing	USGS
<b>In progress</b>		Some debris flow mapping in place. Mapped young debris flow deposits in Tucson area with funding from local flood control district and AZGS; investigations of triggering mechanisms underway. As part of the FEMA-funded Arizona Hazards Viewer, AZGS is making some progress on understanding where slope and geologic conditions are conducive to landslides in Arizona. But much more needs to be done and dedicated funding stream identified for additional study. *Debris-flow mapping is part of every StateMap-funded map. Many undocumented landslides were found while developing the landslide database. Funding is needed to better document and understand these landslides. The greatest threat from landslides, however, are from disturbed areas such as those areas burned by wildfires. Exploring potential funding sources.				
E	Dam	Coordinate with county and community emergency management and floodplain management officials and provide information regarding the locations and potential hazards existing dams so that those communities can make better informed local development decisions.	ADWR	N/A	Annually	N/A
<b>In progress</b>		ADWR regularly inspects all jurisdictional dams. ADWR will in the near future begin a project of low-cost flood inundation mapping using the DSAT/DSS-WISE software developed by the US Department of Homeland Security. This work will greatly increase the number of dams, including those not without development downstream currently, having identified flood inundation limits in the event of dam failure and thereby provide information for informed decision-making which does not currently exist. *ADWR continues to communicate and coordinate with county and local emergency management and floodplain managers in order to				

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		ensure the awareness of existing and new potential hazard areas.				
E	Fissure	Identify and map known fissures across the state.	AZGS	\$65k/year	Sept 2006 & ongoing	State budget
<b>In progress</b>		Completed earth fissure mapping in Maricopa and Pinal Counties, made maps available to public. Seventeen maps published since 2007. Mapping of earth fissures is ongoing. Twenty-two of the original earth fissure study areas have been mapped and the maps are published. All published earth fissure maps are available at AZGS's Earth Fissure Viewer. Over the next several years, the earth fissure program will transform from mapping fissures to monitoring fissure development. *Mapping and monitoring of earth fissures is ongoing and maps are updated as needed. Mapping of all study areas in Cochise County has been completed and published. New study area maps in Pima and Pinal County have been published bringing the total number of fissure study area maps to twenty-six. Updated versions of active study areas in Pinal, Maricopa, and Cochise County have been released.				
N	Disease	Encourage local jurisdictions to consider including Disease and/or Health Issues to their hazard mitigation plans in the future. Disease is now profiled in the State of Arizona Hazard Mitigation Plan in an effort to stay consistent with all other statewide planning mechanisms and for the purpose of THIRA. This will begin when locals begin work on their next hazard mitigation plan updates.	DEMA	N/A	Ongoing	N/A
<b>Delete</b>		* This is not a mitigation measure.				
N	All	Establish a State Mitigation Committee to further the Goals and Objectives of the State mitigation plan through increased integration of State agencies. Identify members from agencies and communities with similar hazard mitigation missions to integrate programs and leverage opportunities. (For local capacity building, reference ideas included in the Local Capability Assessment table earlier in this section.)	DEMA	N/A	Ongoing	N/A
<b>Delete</b>		*No progress has been made and this is not something that will be pursued in the future.				
N	Climate Change	Collaborate with the State Climatologist, ASU and other agencies/organizations to discuss and analyze the potential impacts to Arizona from future climate change. The goal is to utilize the findings to provide outreach to the local jurisdictions to assist them in future mitigation activity.	DEMA	N/A	Ongoing	N/A
<b>Keep/Revise</b>		* Research and workshops are in progress, however, this has not been rolled out to local jurisdictions.				
N	Multi	Assist local jurisdictions in identifying and promoting model ordinances for development in high hazard areas and in adopting the latest building codes such as the International Building Code (IBC) and the International Residential Code (IRC).	DEMA	N/A	Ongoing	N/A
<b>Delete</b>		*The state does not get involved in regulatory issues at the local level.				
N	Climate Change	Incorporate Climate Change and its' potential impacts on the hazards identified in this Plan and other planning mechanisms, as appropriate. Require local jurisdictions to include at least a	DEMA	N/A	Ongoing	N/A

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		discussion on Climate Change in their future hazard mitigation plans.				
Delete		*Climate change has been, and will continue to be, incorporated into this Plan. We will not require local plans to address climate change as it is not required.				
N	All	Promote integration of hazard mitigation into Building Codes, Capital Improvement and Comprehensive Plans. The ideal time for this is as we are assisting the local jurisdictions with their future hazard mitigation plan update process.	DEMA	N/A	Ongoing	N/A
Delete		*This is discussed as part of the planning process with local and tribal communities, this is not an actionable mitigation measure.				